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LRAPP VERTICAL ARRAY

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Westinghouse Research Laboratories

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An earlier report describes a vertical array of acoustic hydrophones that were built in 1972 for measuring noise in the ocean over the frequency spectrum from 10 Hz to 300 Hz. This report describes modifications in the equipment that were made for two deployments at the Blake Basin in the Atlantic Ocean.

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1. INTRODUCTION

A set of low noise, high sensitivity acceleration canceling hydrophones were built and tested in 1972 for winchable vertical arrays to be used at depths to 5,000 meters. In the spring of 1973 cables and associated equipment were prepared for two deployments on the Blake Plateau. A single hydrophone is shown in Fig. 1, an array of hydrophones reeled onto a drum is illustrated in Fig. 2, and a partially exploded view of a cable connector is shown in Fig. 3.

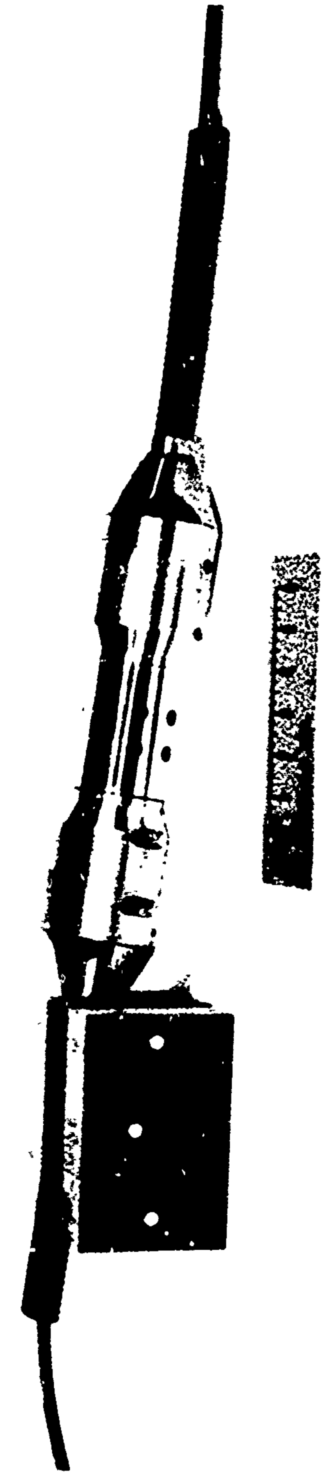

Fig. 1 - Westinghouse Model WX-VERAY-1 Hydrophone

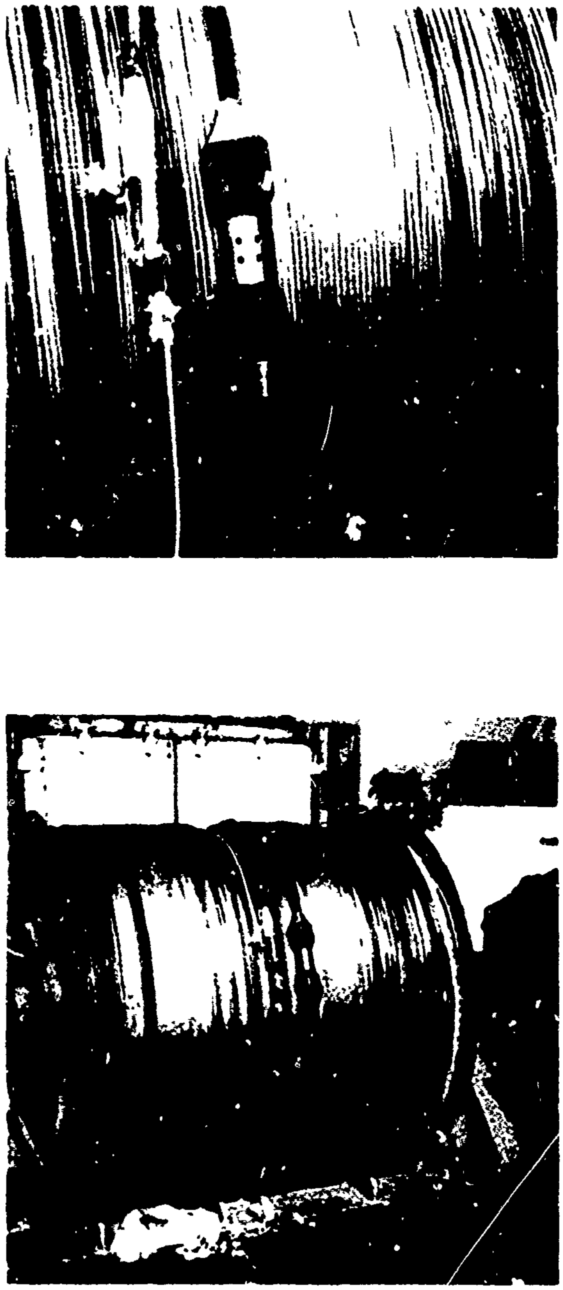

Fig. 2 - Reel with a 4,000 Meter Array Containing Six Hydrophones

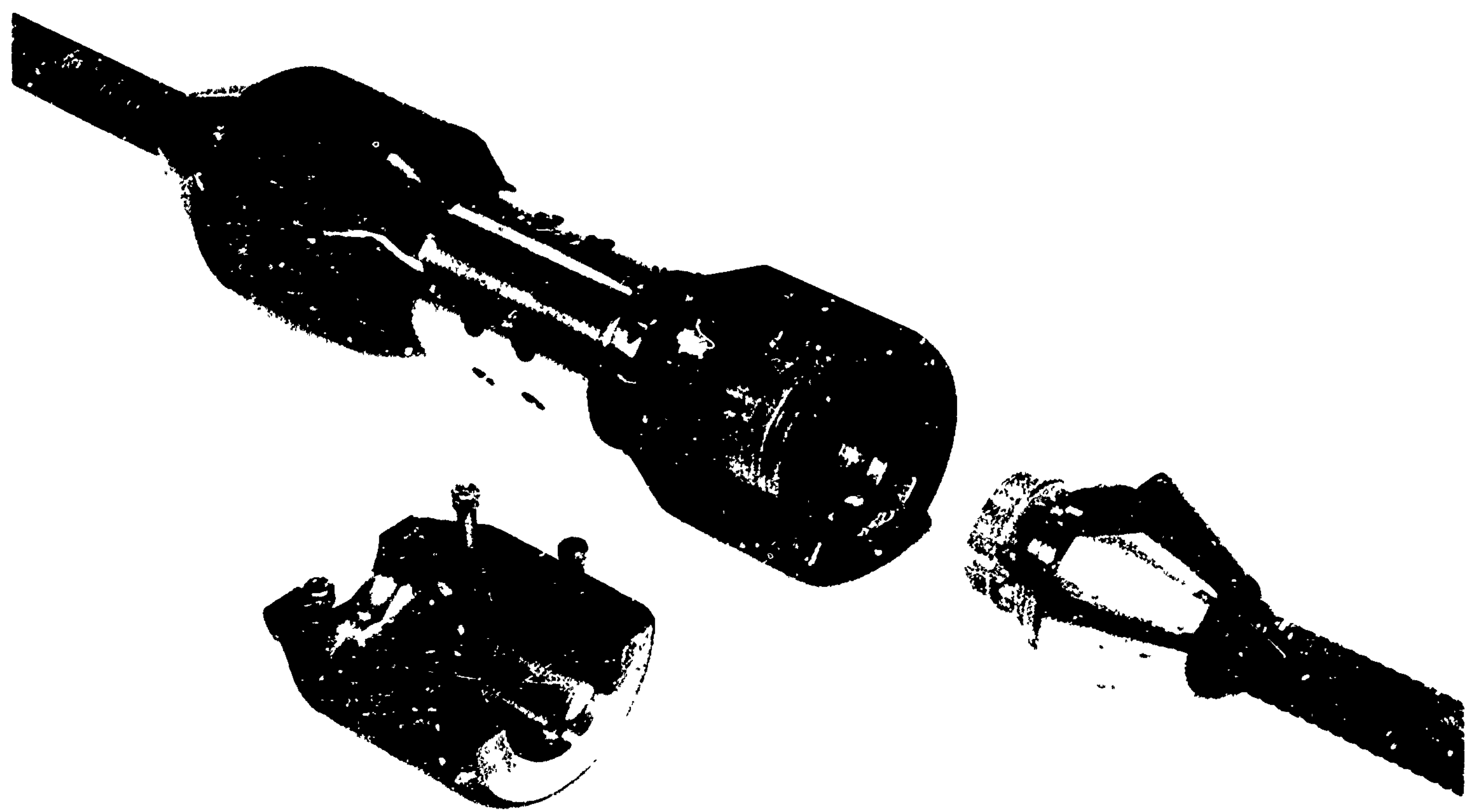

Fig. 3 - Hydrophone with Upper End Connected to a Cable and Lower End Disconnected to Show Potted Preamplifier and Electrical Connector

2. HYDROPHONES AND PREAMPLIFIERS

The hydrophones were basically the same units that were used in the November 1972 tests and which have been described in previous reports.[1,2] However, it was found that silver coating on most of the ceramic cylinders was attacked by sulfur so that patches of the coating became nonconducting. These cylinders were replaced by ones with a nickel coating and a gold flash. These h ve proven very satisfactory.

Some of the potted preamplifiers attached to the hydrophones as illustrated in Fig. 3 behaved in an erratic way. Although the surfaces of all of the semiconductor elements were passivated before being potted in polyurethane the forces exerted during pressure cycling sometimes caused the gain of the amplifiers to drop to zero. Therefore, as a back-up effort, experiments were made with two new encapsulation methods. The first consisted of cutting off the lids of the transistor cans, attaching a Tygon tube filled with moisture-free castor oil. The second method consisted of sealing the units inside of a pressure tight aluminum cylinder. Figure 4 shows three transistors with oil-filled tubes attached. On the left is an aluminum capsule covered with black tape. Both types of encapsulation proved satisfactory under pressure cycling. The second method was chosen because it isolates the semiconductor assembly from any large pressure changes. Before being tested at the Naval Research Laboratory at Orlando, Florida, hydrophone-preamplifiers are pressure cycled 10 times to 55 MPa at 4°C. The pressure is increased linearly over a 15 minute period in order to avoid damaging the low noise input stage of the preamp.

Fig. 4 - Preamplifier with Three Oil-Filled Transistor Cases and One Aluminum Pressure Capsule

3. CABLES AND CONNECTORS

The cable lengths used in the two Blake Deployments are shown in Fig. 5. A new coupling unit shown in Fig. 6 was designed which made it practical to couple cables B and D together to provide a 7,600 ft cable length. The new cables, H, I. J, and K were made as described in reference 2. In the 1972 deployment some of the connectors were damaged because water failed to flow into the space behind the connector. These connectors were potted into the mechanical cone which clamped the steel cable strands. In order to prevent a pressure buildup, two holes were drilled to provide easy access for free flooding behind the connector. Broken hollow roll pins were replaced with solid index pins.

In order to facilitate connection of the cable connectors, the fixture shown in Fig. 7 was built. This made it easy to hold the two parts of the connector while the split coupler was being assembled.

A detailed report[3] covering the cables, terminations, and connectors was written by C. Hikes of W OR&EC.

A split metal cylinder is used to couple the cable to the hydrophone. Figure 3 shows half of such a cylinder in place around the male connector and the preamplifier and the other half removed. Before assembly the "O-ring" groove was coated with Dow Corning #4 Silicone Dialectric. The inside surface of the split coupler was coated with Lubriplate made by Fisk Bros. Refining Corp. to reduce corrosion and to make it easier to assemble the coupler. After the deployment it was found that on many of the hydrophones the split cylinder had pinched the polyurethane and caused the connector to leak. The inside diameter of the coupler will be increased to eliminate the pinching problem.

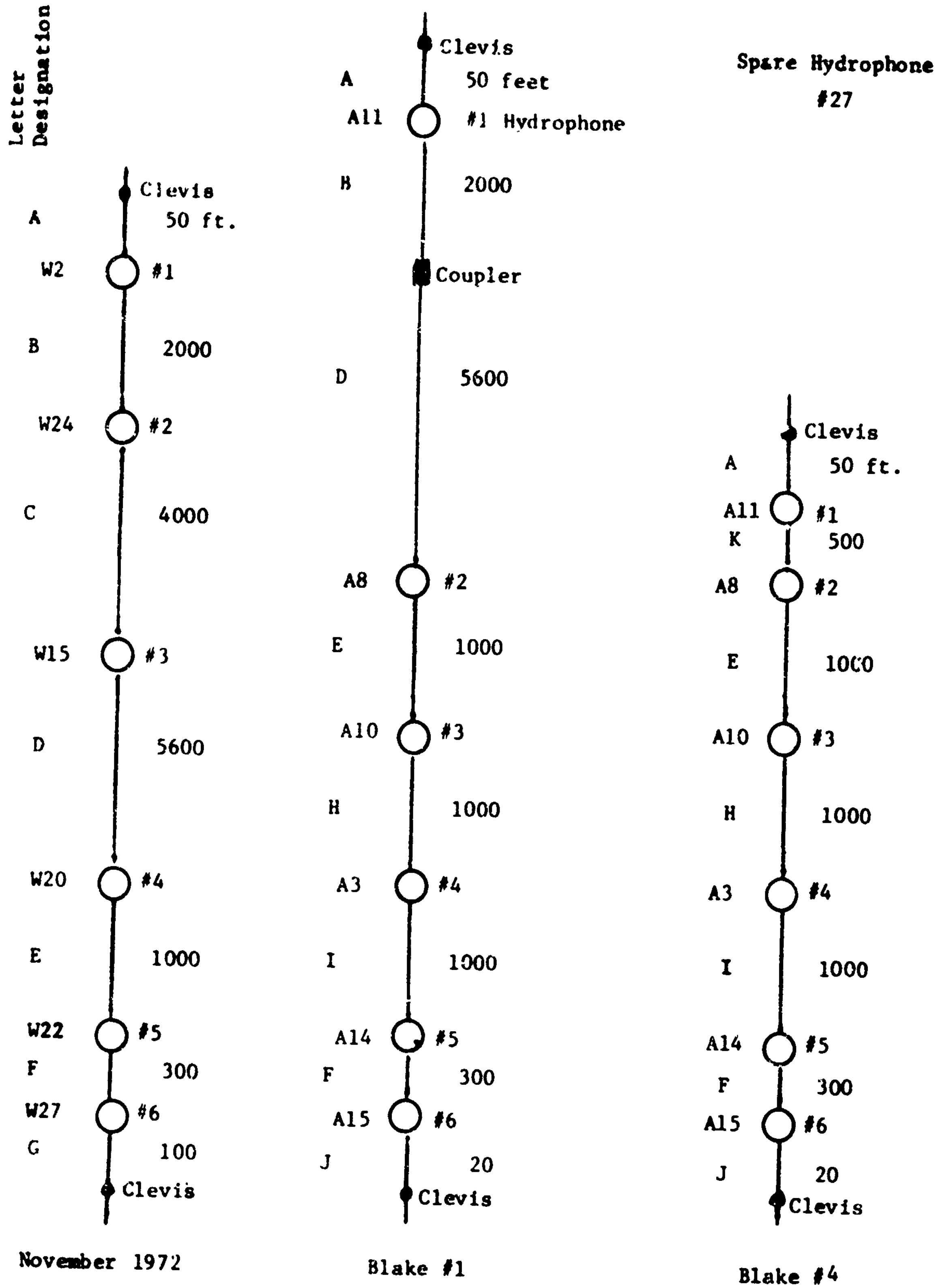

Fig. 5 - ACODAC Configurations of ") Hydrophones with Cable Designation Letters

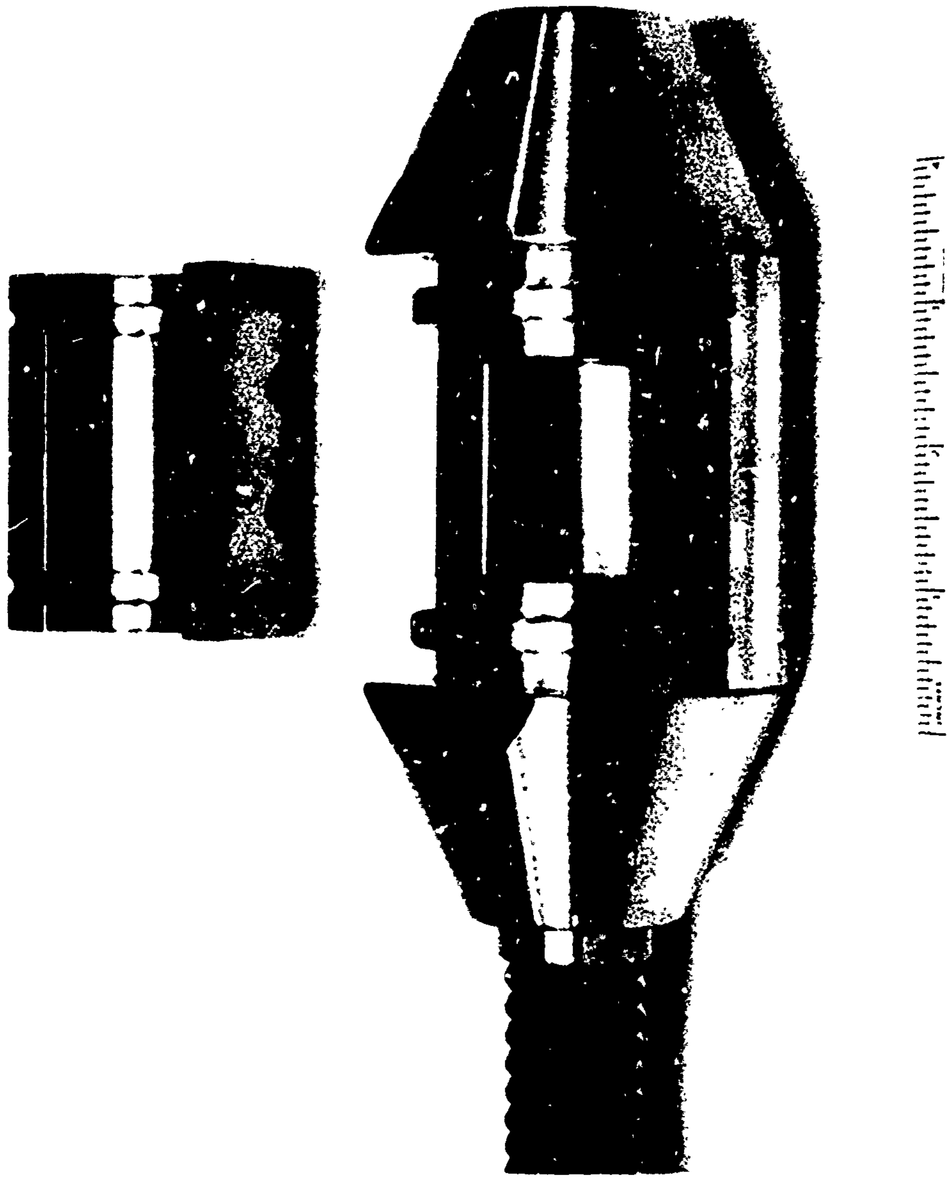

Fig. 6 - Coupler Unit for Attaching Two Cable Sections

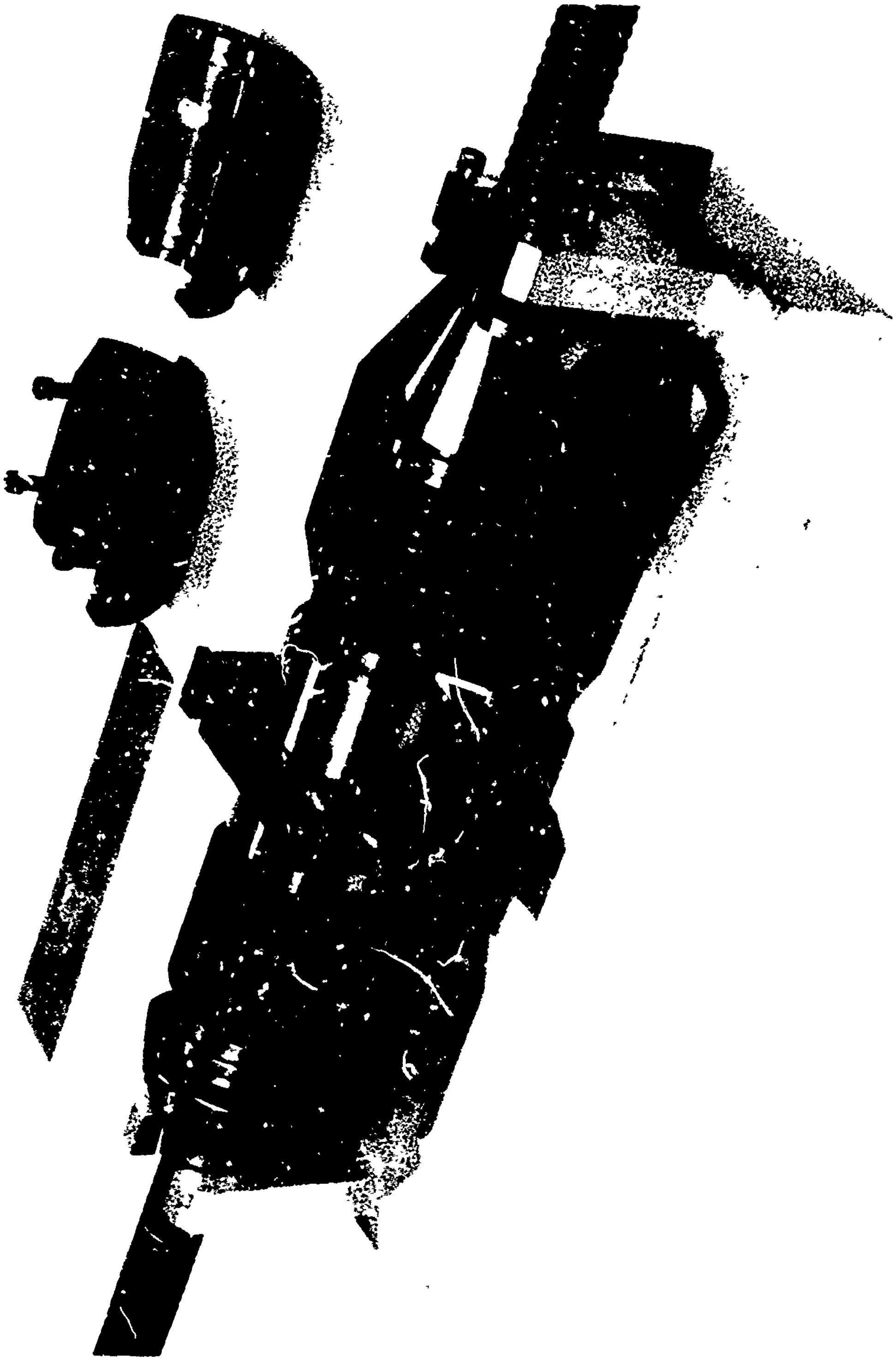

Fig. 7 - Hydrophone Held in a Fixture for Connecting the Unit to a Cable

4. TEST AMPLIFIER

In order to make electrical calibration runs with the RPM (record power module) and the cables, three dummy amplifiers, designated J, K, and L, were built and tested. These were identical to the hydrophone preamplifier circuits except that they had an impedance connected to the input to simulate the measured transducer impedance. See Fig. 8. The gain of these three units is given in Table 1 and is shown graphically in Figs. 9, 10 and 11.

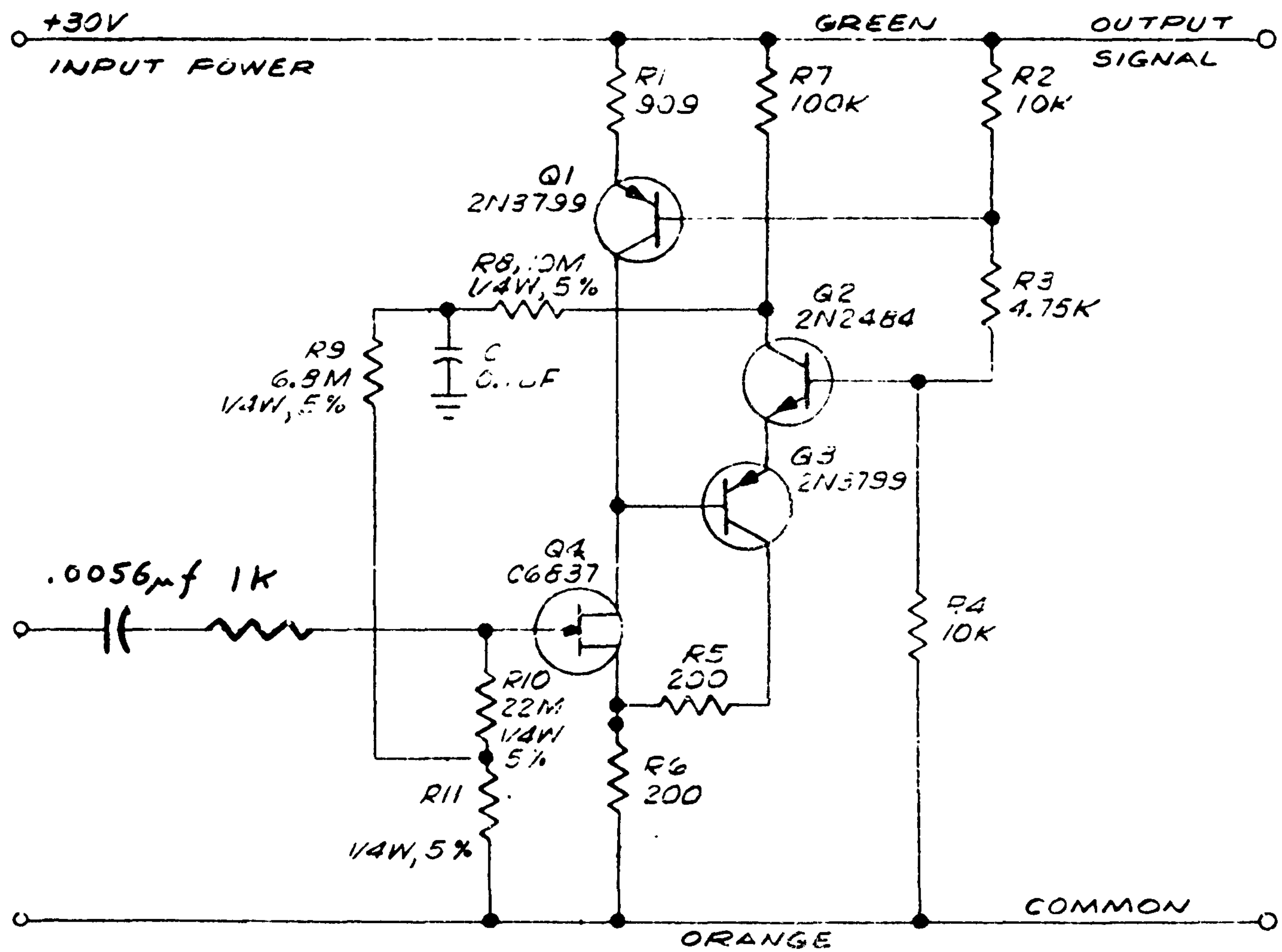

Fig. 8 - Dummy Amplifier Schematic

Table 1 - Gains of the Three Dummy Amplifiers with the Orlando Termination Amplifier

Frequency Hz	Gain in dB		
	Unit "J"	Unit "K"	Unit "L"
1000	59.6	59.7	59.7
700	59.7	59.8	59.8
500	59.8	59.9	59.8
200	59.8	59.9	59.9
100	59.8	60.0	59.9
70	59.8	59.9	59.8
50	59.8	59.9	59.9
20	59.8	59.8	59.8
10	59.9	59.8	59.6
7	61.0	60.0	59.6
5	61.3	61.0	60.0
3.0	--	--	63.2
3.3	--	65.6	--
3.5	66.4	--	--
2	46.0	48.9	52.0
1	32.0	32.0	38.1

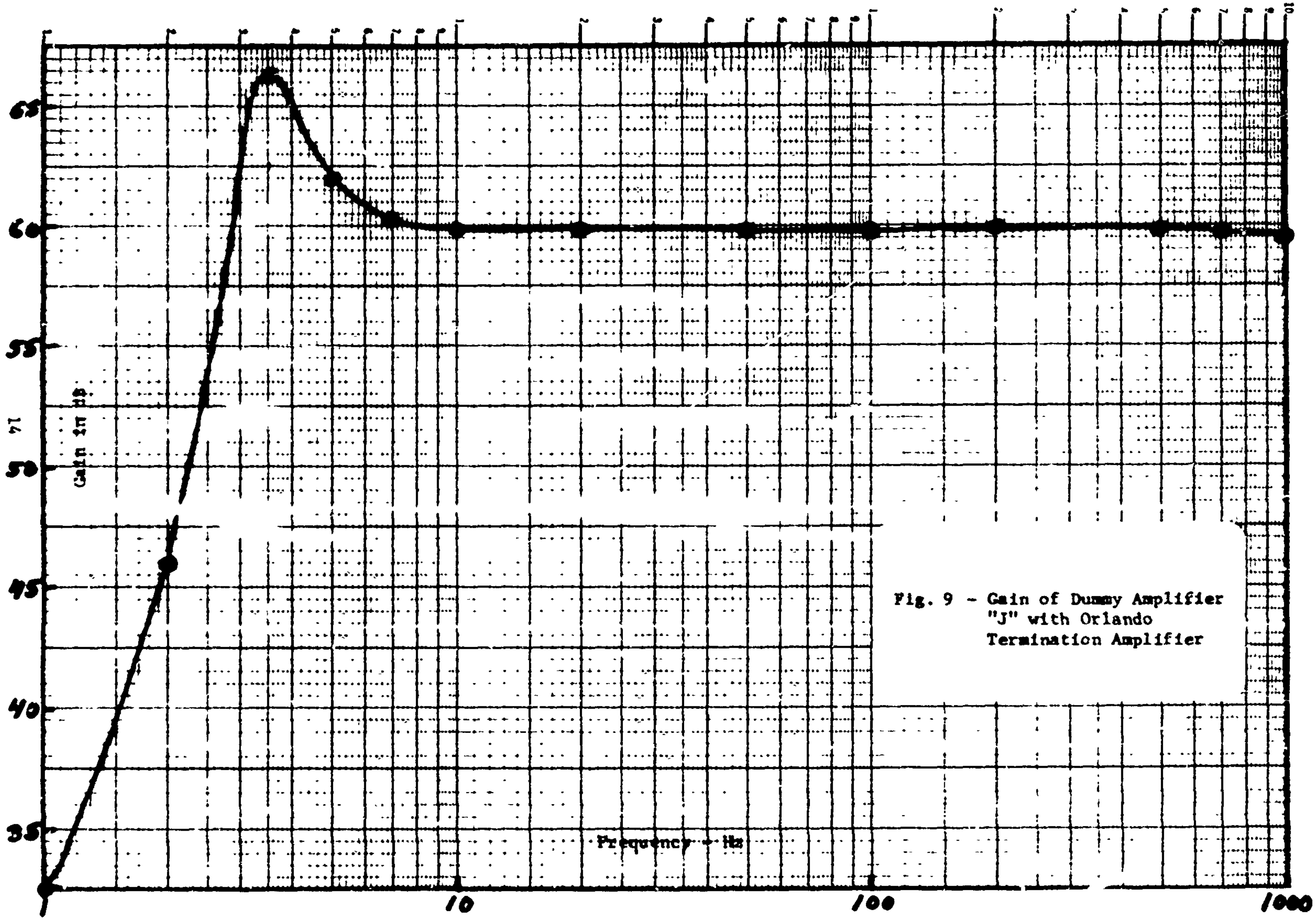

Fig. 9 - Gain of Dummy Amplifier "J" with Orlando Termination Amplifier

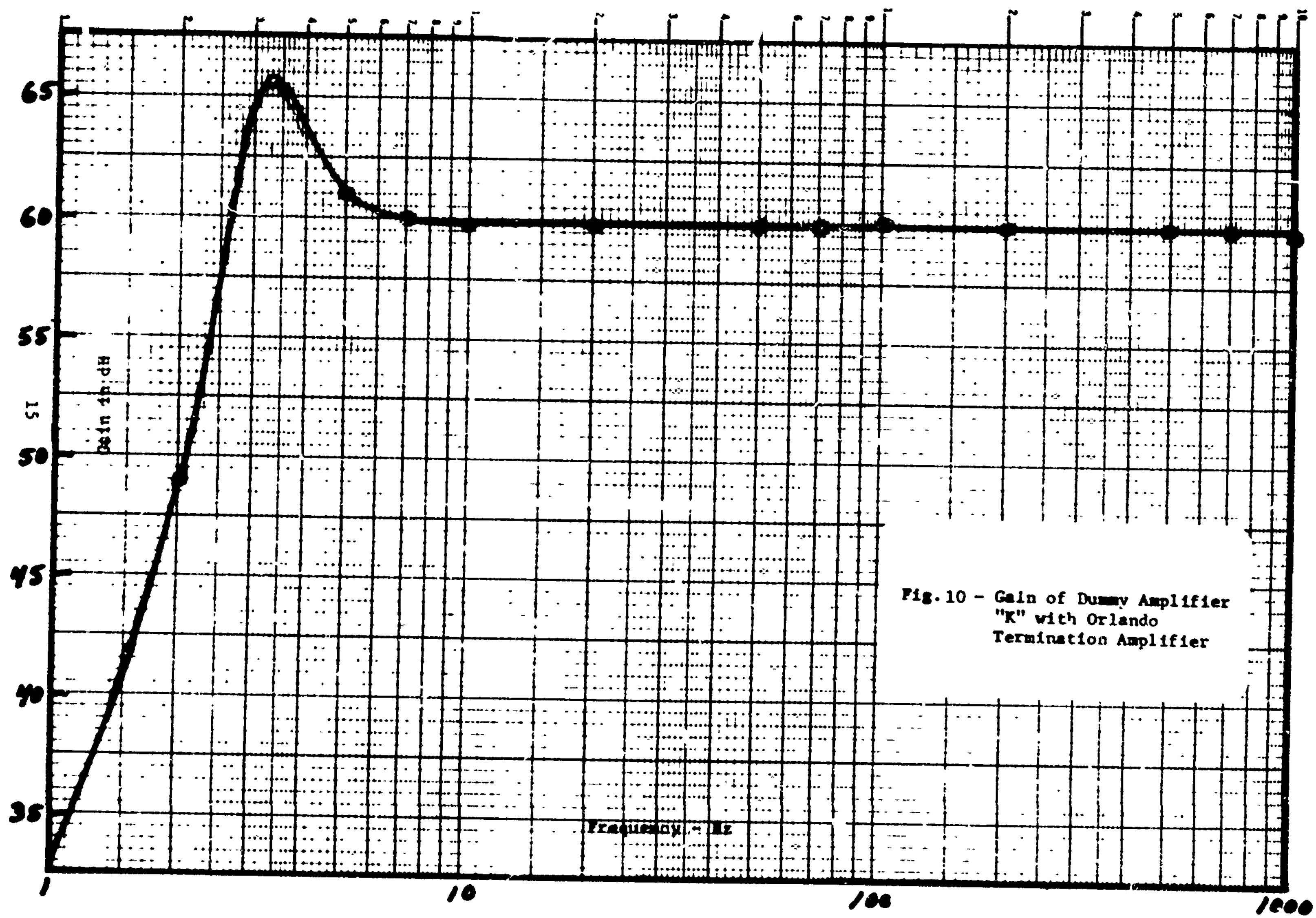

Fig. 10 - Gain of Dummy Amplifier "K" with Orlando Termination Amplifier

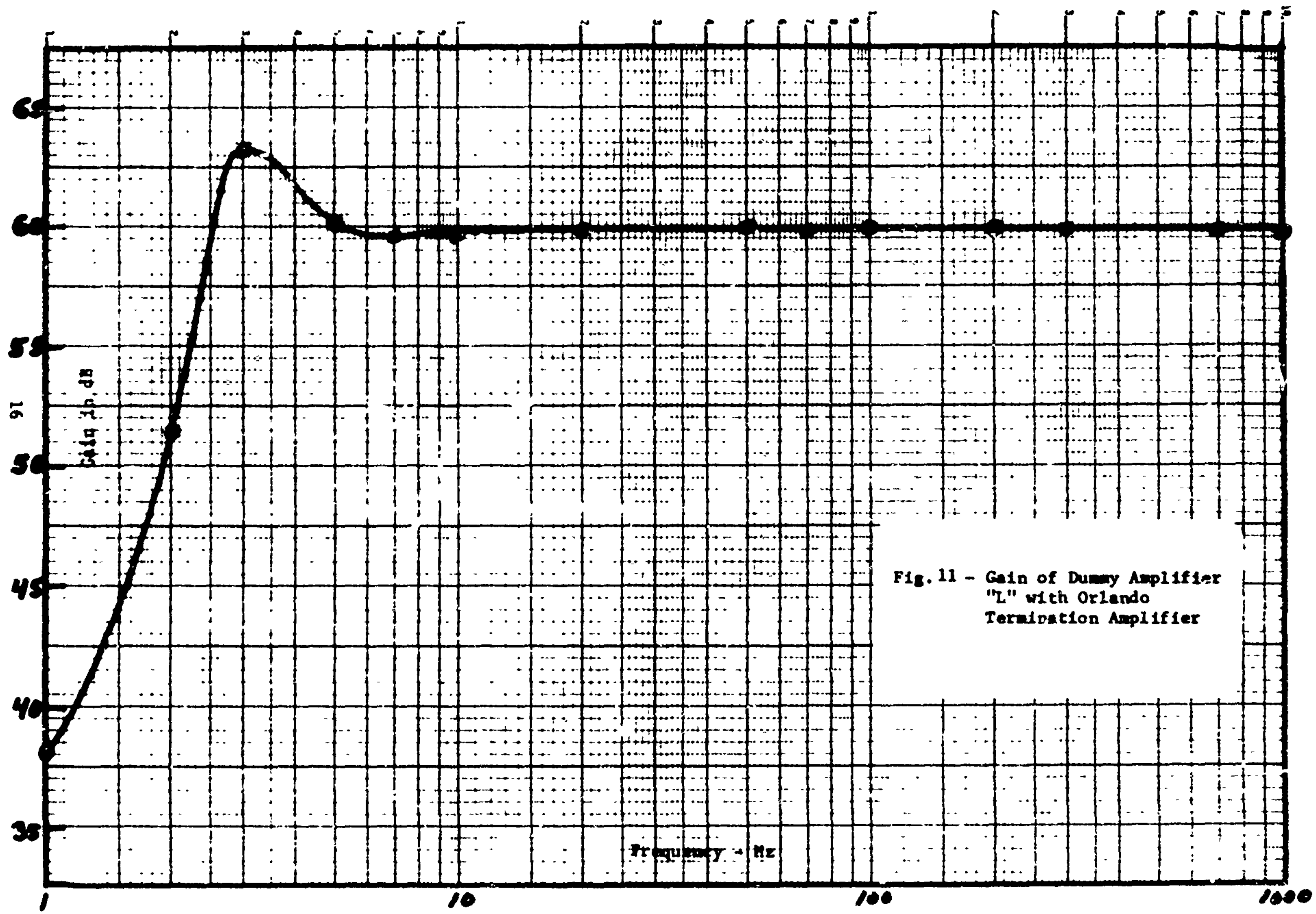

Fig. 11 - Gain of Dummy Amplifier "L" with Orlando Termination Amplifier

5. HYDROPHONE SYSTEM SENSITIVITY AND TERMINATION AMPLIFIERS

In order for the hydrophone system response to be able to cover the signal level dynamic range of the Blake Deployment operation, i.e., the high source level signals from high power projectors and explosive charges and lower level ambient noise signals, the sensitivity of the Westinghouse hydrophone systems were set at -149 dB re 1 V/μPa. In the previous operation, sensitivity had been set at -129 dB re 1 V/μPa. The reduction in gain was accomplished by reducing the gains of the termination amplifiers. The six amplifiers in each of the two termination boxes, X and Y, were modified.

In order to ensure that each of the six hydrophone systems have similar sensitivities, two resistors in each termination amplifier are adjusted to compensate for the impedances of the various cable lengths. This equalizes the dc voltage on all preamplifiers and it also equalizes the ac load on all preamplifiers. In the Ⓦ system, dc power is fed from the record power module (RPM) up the cable to the preamplifier instead of having battery packs at each hydrophone. The ideal resistance values, along with the cable lengths for Blake Deployments #1 and #4, are shown in Tables 2 and 3. The R1 resistors were first chosen so that the ac load on all preamplifier units would be identical. Then the R2 values were chosen such as to make the dc voltage on all preamplifiers equal.

When it was decided that the RPM unit was not to be opened between deployments #1 and #4, it became necessary to choose values for R1 and R2 which would be a satisfactory compromise for the two sets of cable lengths. The values used are given in Table 4.

The termination amplifier units were modified so that they could be easily plugged into place or removed when resistor values have to be changed.

TABLE 2

Ideal Resistance Values for Termination Amplifiers for Blake Test #1

Hydrophone Location Number	R1 ohms	R2 ohms	Length in Meters	Cable Designation
				A
1	0	694		
			2310	B&D
2	171	694		
			305	E
3	194	685		
			305	H
4	216	685		
			305	I
5	238	740		
			92	F
6	245	753		
			6	J

TABLE 3

Ideal Resistance Values for Termination Amplifiers for Blake Test #4

Hydrophone Location Number	R1 ohms	R2 ohms	Cable Lengths in Meters	Cable Designation
				A
1	160	694		
			152	K
2	171	694		
			305	E
3	194	685		
			305	H
4	216	685		
			305	I
5	238	740		
			92	F
6	245	753		
			6	J

TABLE 4

Actual Resistance Values Used for Both Blake #1 and #4 Deployments

Hydrophone Location	R1 ohms	R2 ohms
1	0	774
2	172	693
3	193	685
4	216	685
5	239	740
6	245	752

6. POWER CONVERTER

A revised power converter block diagram is given in Fig. 12. In the 1972 deployments the low impedance signal that turned the unit off when the break-away connector was exposed to sea water came from pin #6 (hydrophone #6). Since pin #7 was available and unused, we decided this would give a larger change in impedance due to sea water across the terminals upon "break-away".

The revised power supply schematic is given in Fig. 13 and the new regulator circuit is shown in Fig. 14. With reference to Fig. 13, Q7A was added in order to obtain a lower voltage drop across transistor Q7 in order to improve the positive peak of the square wave voltage into the transformer, T1. Diodes D1, D2, and capacitor, C13, were added to insure self start-up of the multivibrator when dc power was applied. An improved shutdown circuit consisting of Q11 and associated components was added. This will be activated when the impedance drops below 25,000 ohms as a result of exposure of the breakaway connector to sea water. Q10 and SCR1 were used to replace two transistors in order to improve the reliability of the shutdown circuit.

Referring to Fig. 14, the Zener diode, D32, was replaced with R40 and C35 so as to allow a greater range of power converter output voltages. The desired output voltage is a function of the array length.

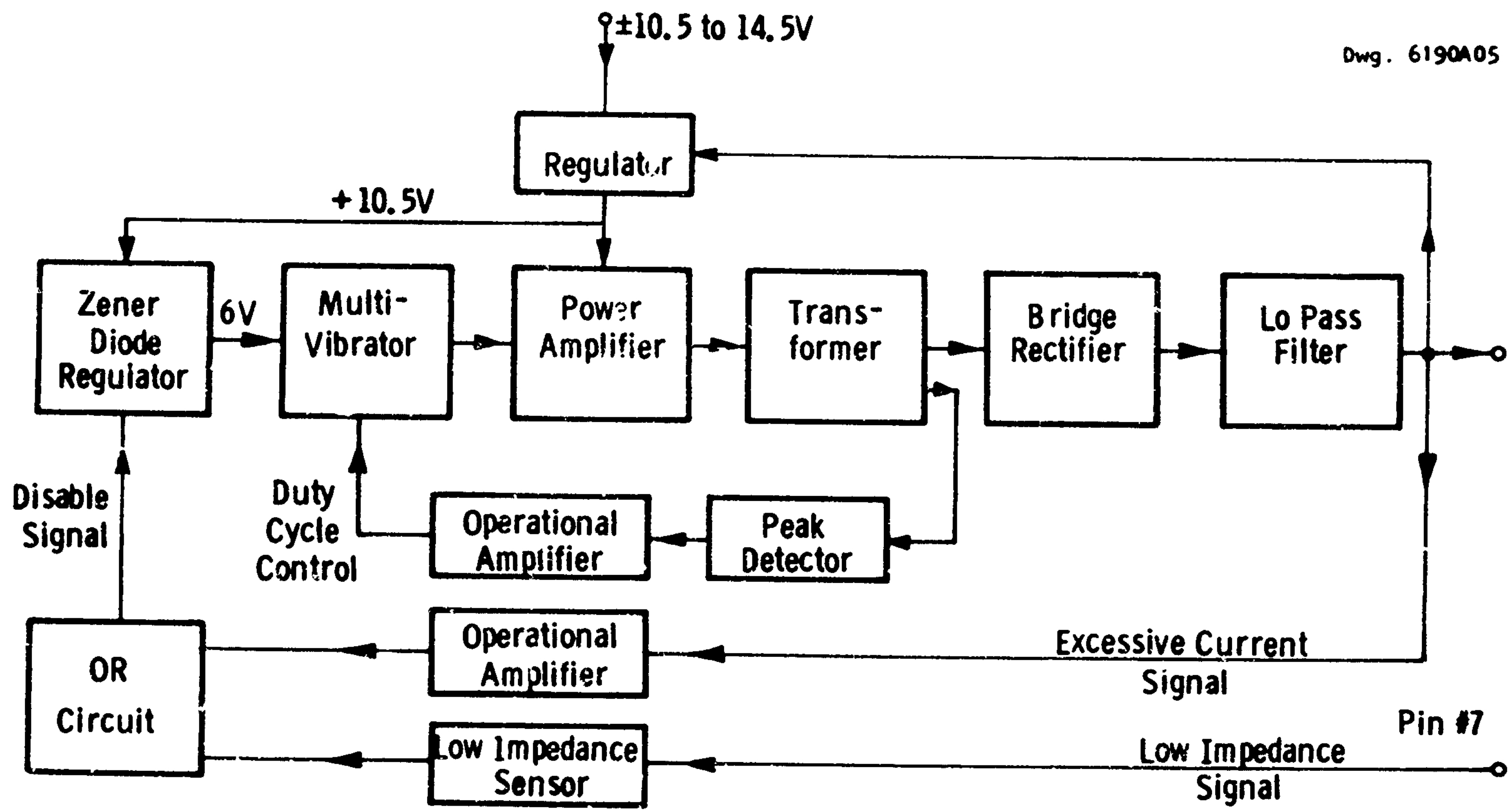

Fig. 12 - Up Converter, Voltage Regulator, and Protective Circuit

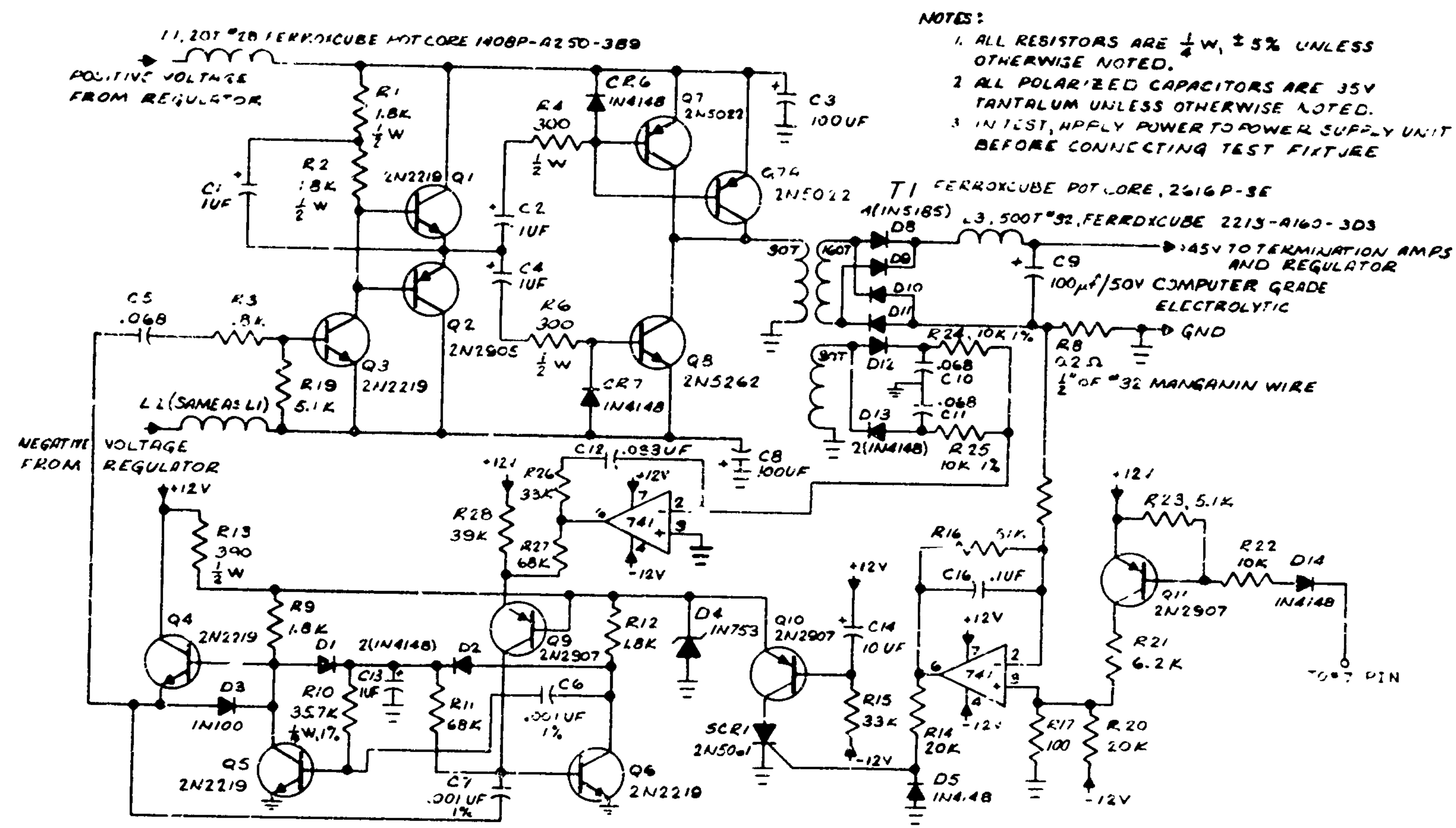

Fig. 13 - 1973 Power Supply Unit for ACODAC

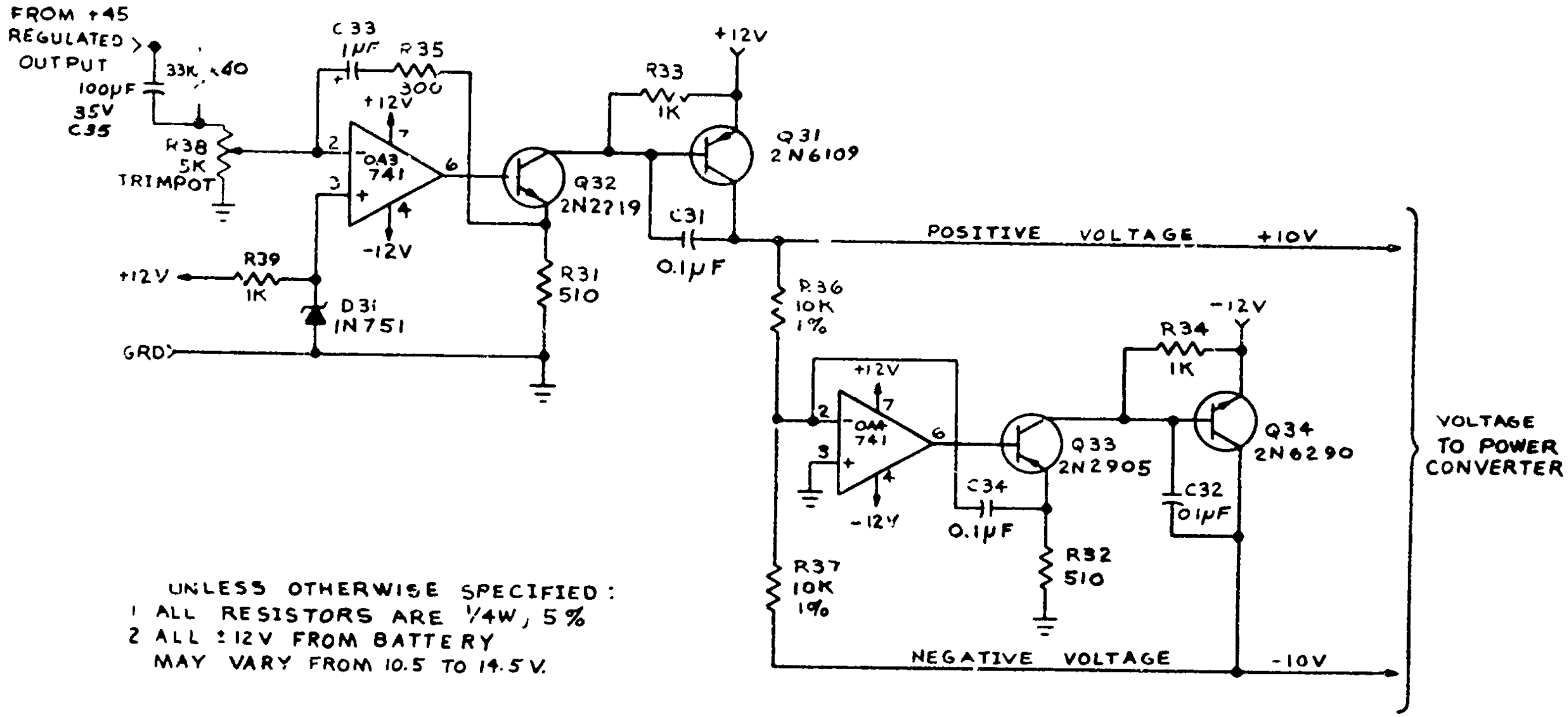

Fig. 14 - Regulator Used on 1973 Blake Deployment

7. TESTS

Before deployment four sets of tests were made. After testing at ⓦ R&D in Pittsburgh, Pa., the hydrophones were calibrated by the Naval Research Lab at Orlando, Florida. The hydrophones were connected to the cable sections at Environ-Electronics Corp. in Jupiter, Florida and a series of tests were run. Next the cables were sent to the R/V North Seal at Galveston, Texas where tests were made with the electronics package containing the magnetic tape recorder.

7.1 Orlando Tests

Hydrophones A11, A8, A10, A3, A14, and A15 were calibrated by the Naval Research Laboratory Underwater Sound Reference Division and the results are given in tabular form in two reports prepared by that laboratory.[4] Some of their results have been graphed and are shown in Figs. 15, 16, 17, and 18. Note that all units had flat responses from 10 Hz to 300 Hz. They had a peak response at 3 Hz to 4 Hz which unfortunately will give a large response to cable strumming at 3.5 Hz. It is desirable to reduce the response below 10 Hz. A response of the type illustrated by Fig. 19 would be more desirable.

All units exhibited a reduction in sensitivity of about 3 dB in going from 0.7 to 55 MPa of hydrostatic pressure. See. Fig. 20. The change is believed to be due to the change in the compliance of the silicone oil inside the ceramic cylinder with the change in static pressure. The sensitivity as a function of pressure will be determined the next time hydrophones are calibrated.

7.2 Pittsburgh Tests

Before the hydrophones were tested with the cables they were tested by using resistors to simulate the impedance of the wires in

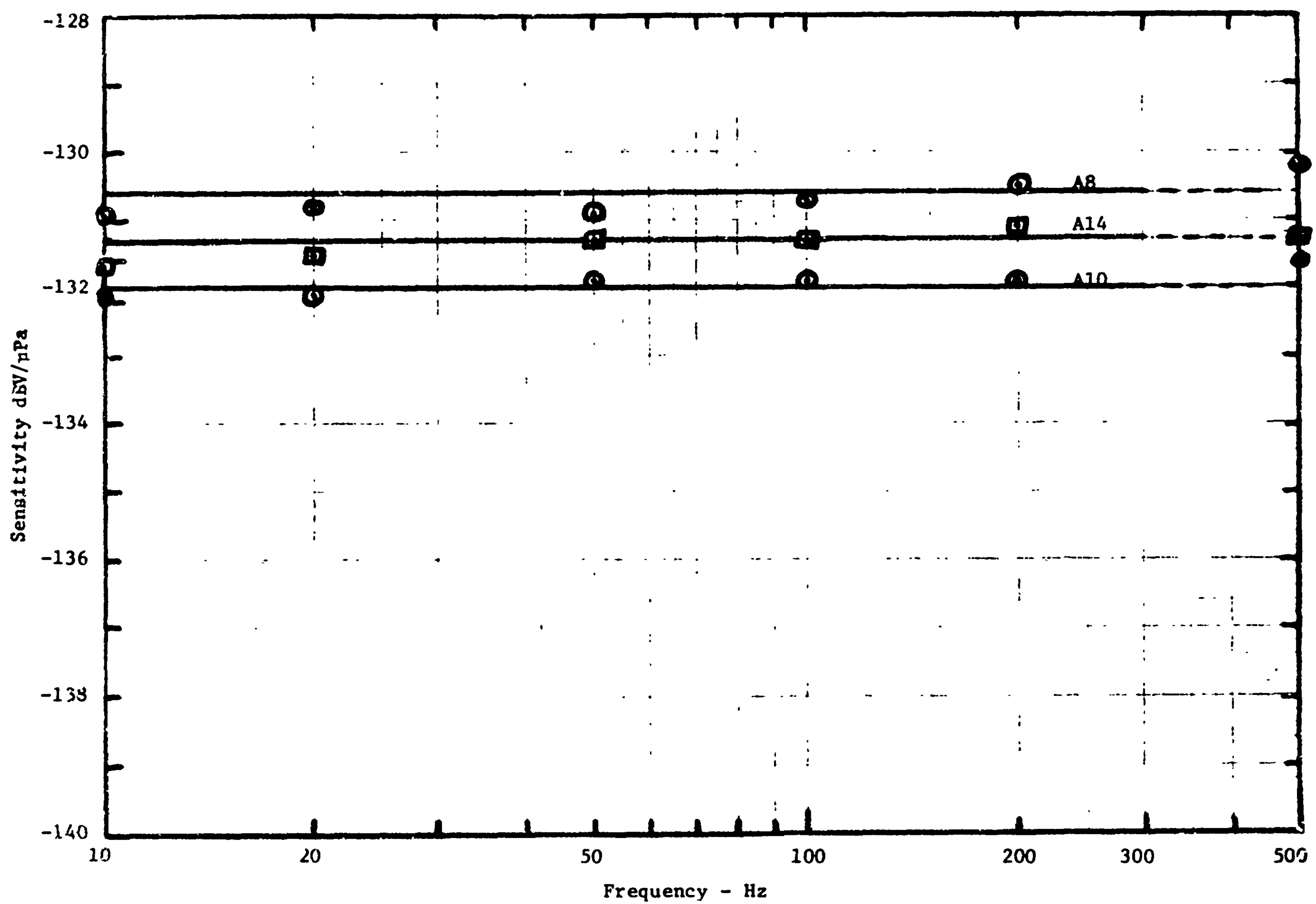

Fig. 15- Sensitivity at 5510 Meter Depth of A8, A10 and A14 Units

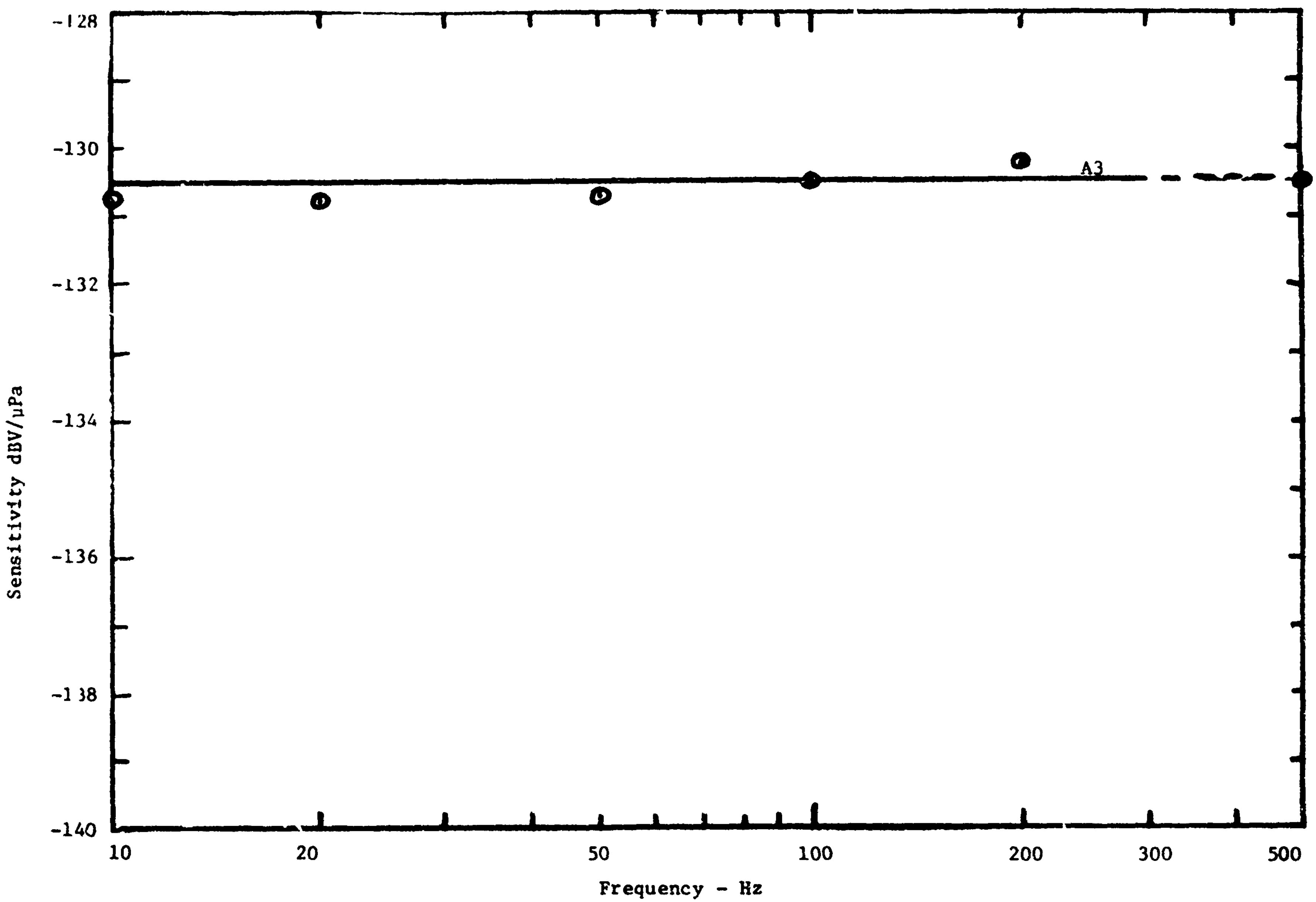

Fig 16- Sensitivity at 5510 Meter Depth of WX-VERAY-1 Hydr.phone, Serial A3

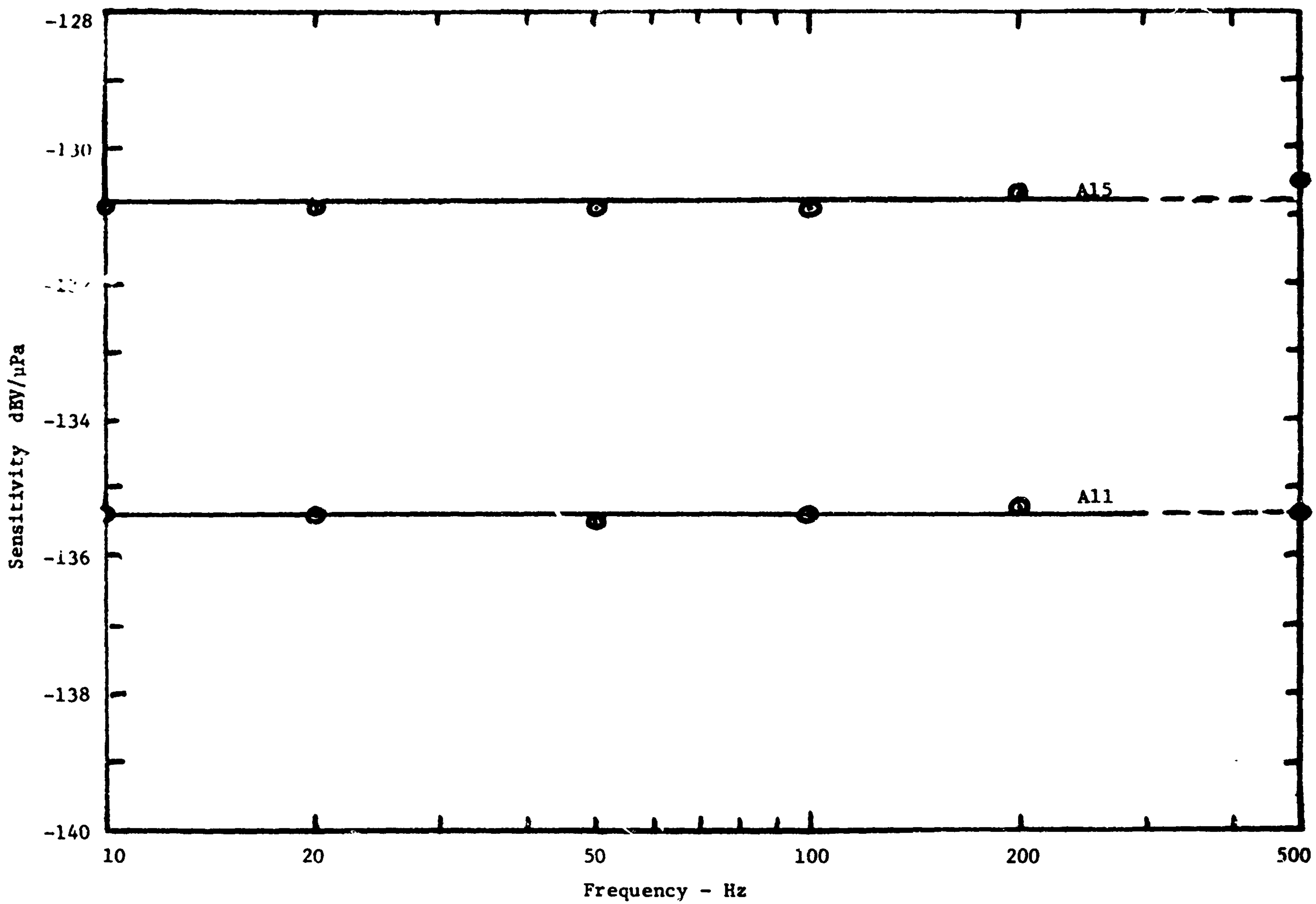

Fig 17 - Sensitivity at 5510 Meter Depth of A11 and A15 Units

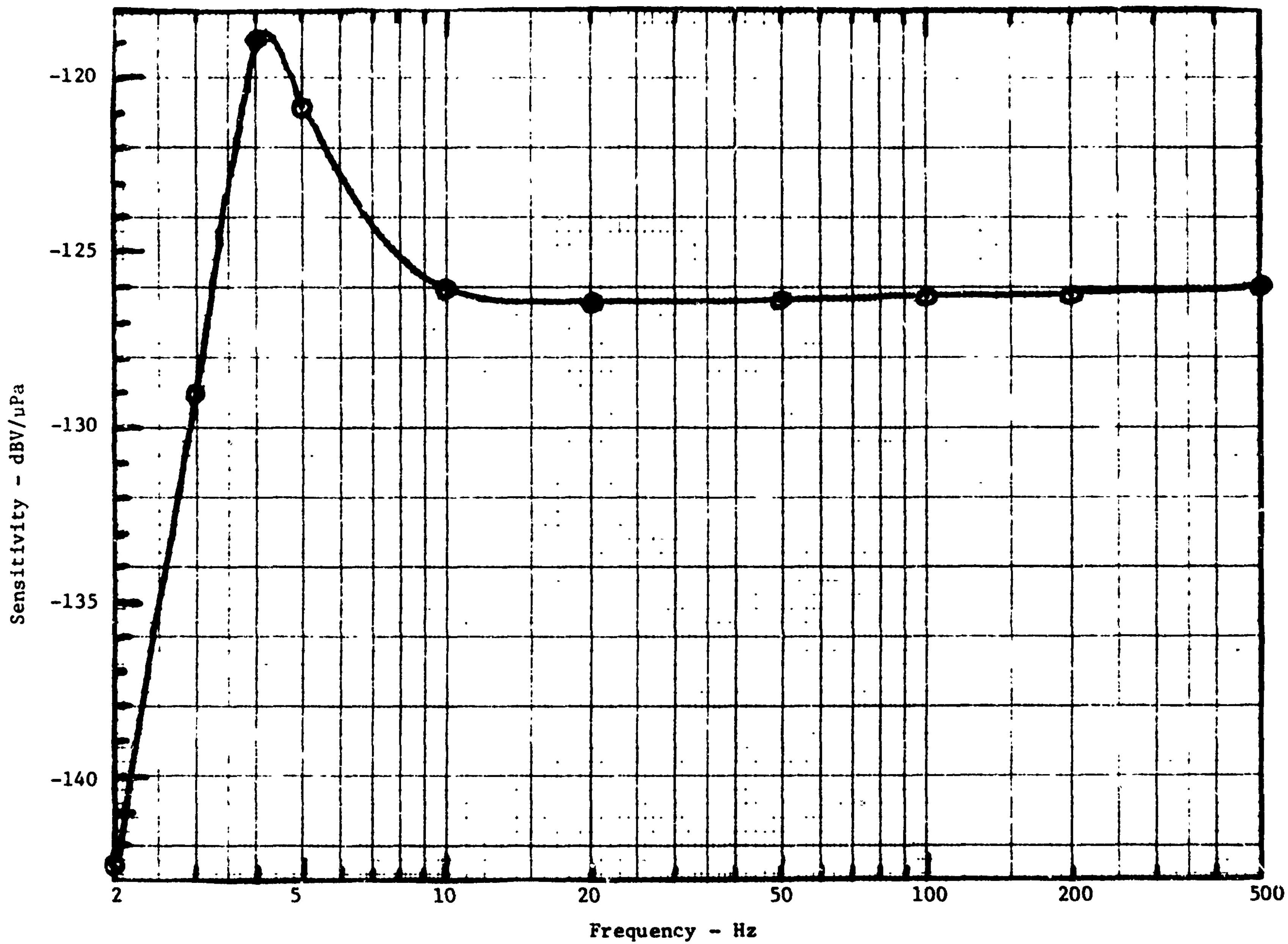

Fig. 18 - Frequency Response of WX-VERAY-1 Hydrophone Serial #27

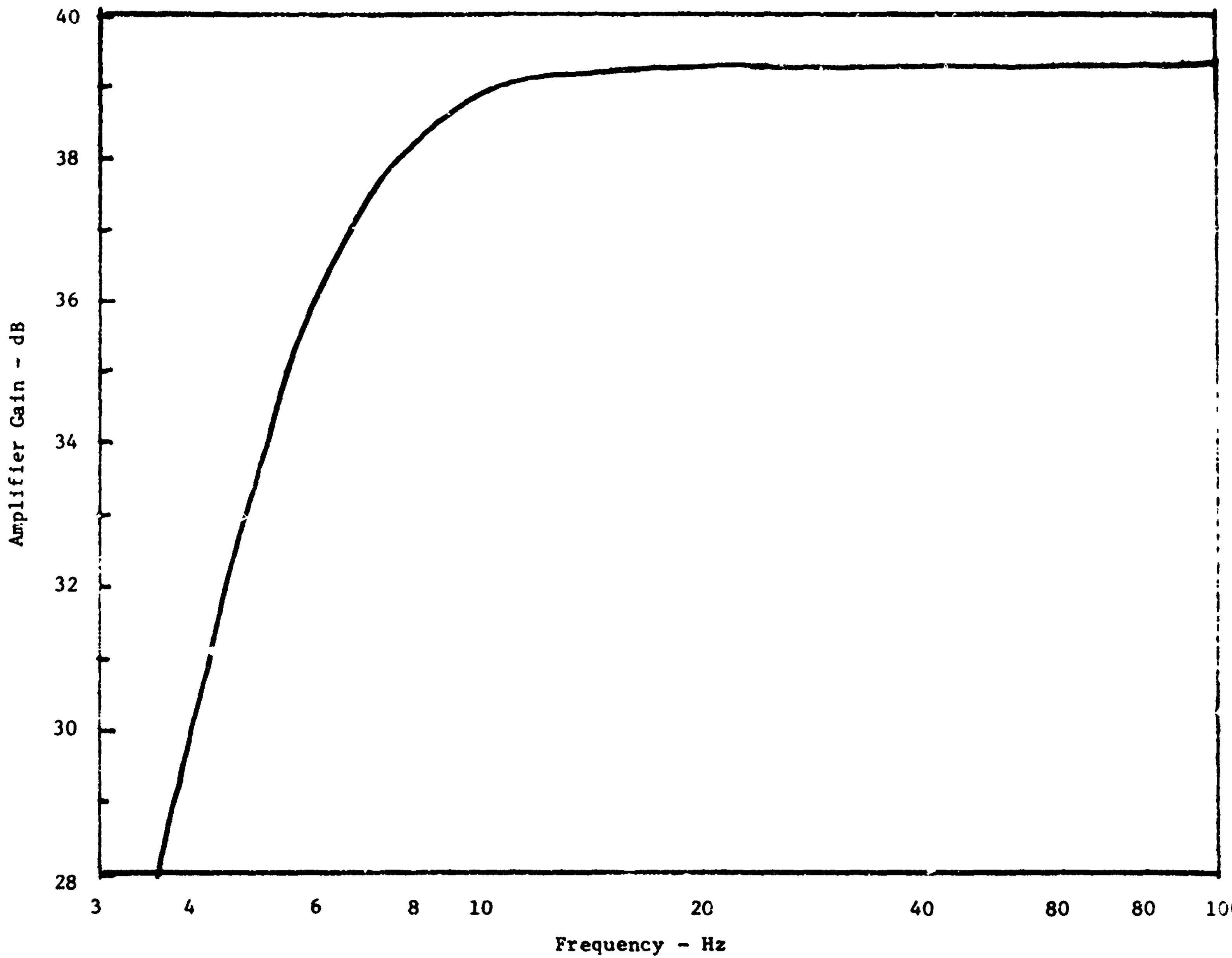

Fig. 19 - Desired Amplifier Frequency Response to Reduce Sensitivity at Strumming Frequency

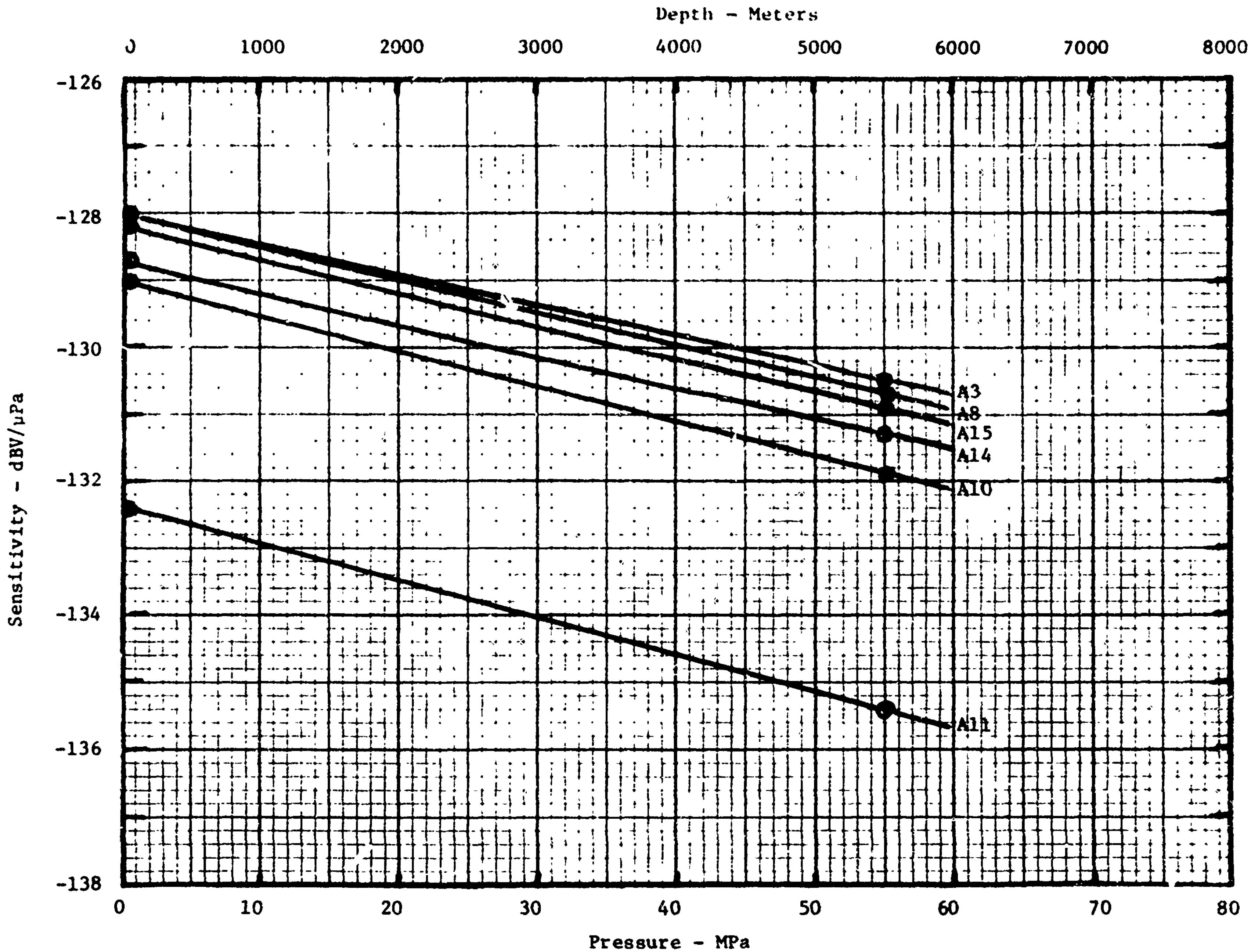

Fig. 20 - Change in Sensitivity with Ambient Pressure of WX-VERAY-1 Hydrophones

in the cable. The cable capacity was not simulated. These tests indicated that the cross talk between any two channels due to mutual resistance alone was less than -70 dB.

Hydrophones with preamp assemblies were pressure cycled to 55 MPa at 20°C. The sensitivity was measured before and after the pressure cycling.

To insure proper operation of the converter unit when battery voltage is applied, a set of tests were made at both 10.5 and 14.5 volts. Both positive and negative voltages were turned on simultaneously, then the positive voltage was applied a fraction of a second before the negative voltage, and lastly the negative voltage was applied before the positive voltage. The converter functioned satisfactorily in all cases.

To simulate the exposure of the break-away cable to sea water, a 25 k ohm resistor was connected between coax lead #7 and ground. This test was repeated a number of times and the converter unit always shut off. (The 25 k ohms simulated the expected sea water impedance.)

To simulate a faulty hydrophone a 100 ohm resistor was connected between pins #1 and #7 of Channel #1. The converter unit shut off. The normal dc impedance of a hydrophone is 2000 ohms.

7.3 Jupiter Tests

Test records #1 to #31 were made in Jupiter, and given to the Deputy Test Director. The gain of all six amplifier channels were measured from 10 Hz to 300 Hz and the results are given in Figs. 21 and 22. The gain of channel #6 was measured at 100 Hz at input levels from 1 to 10 mV. The gain was unchanged as the battery voltage was varied from 10.5 to 14.5 volts.

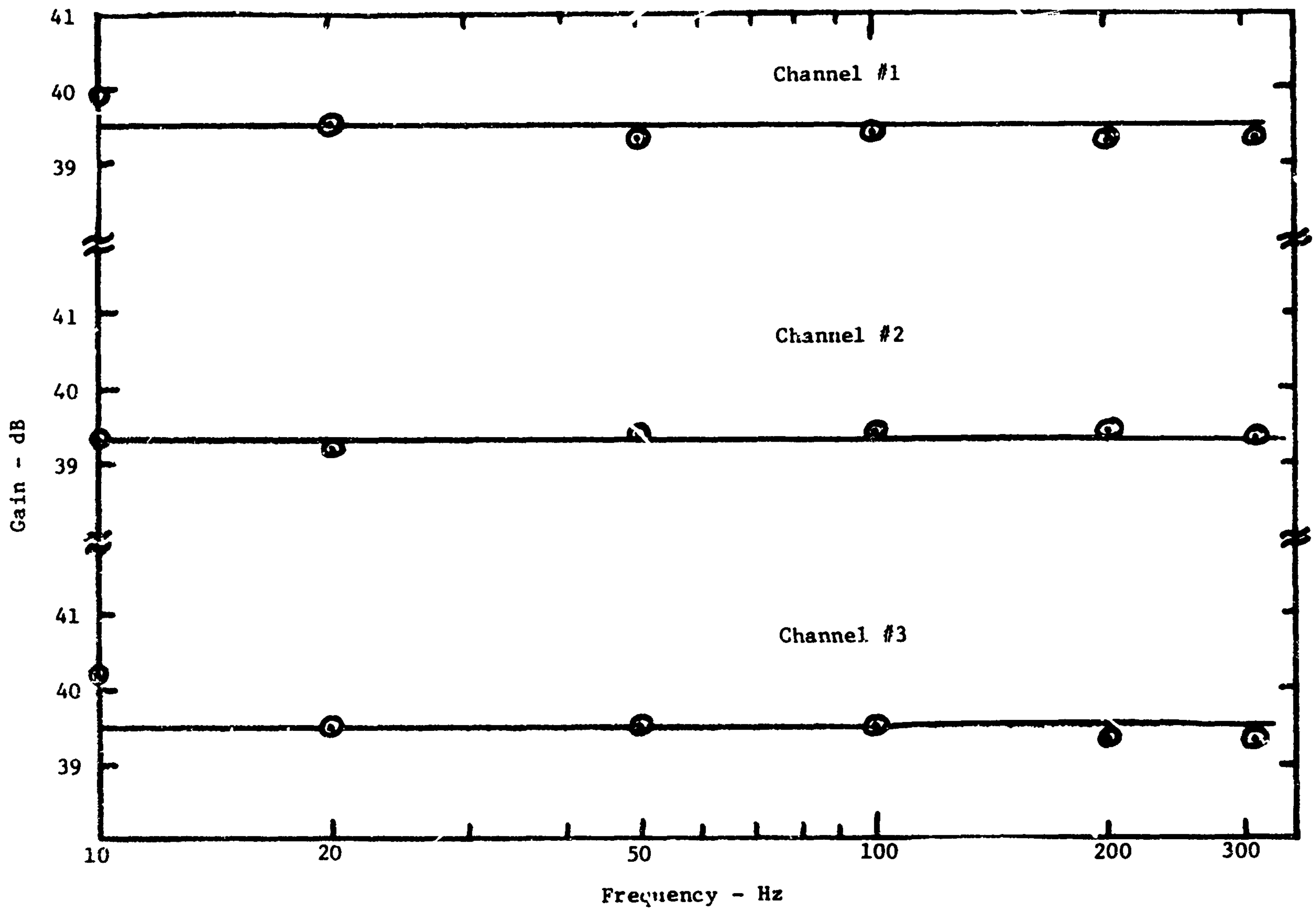

Fig.21 - Gains of Amplifier Channels

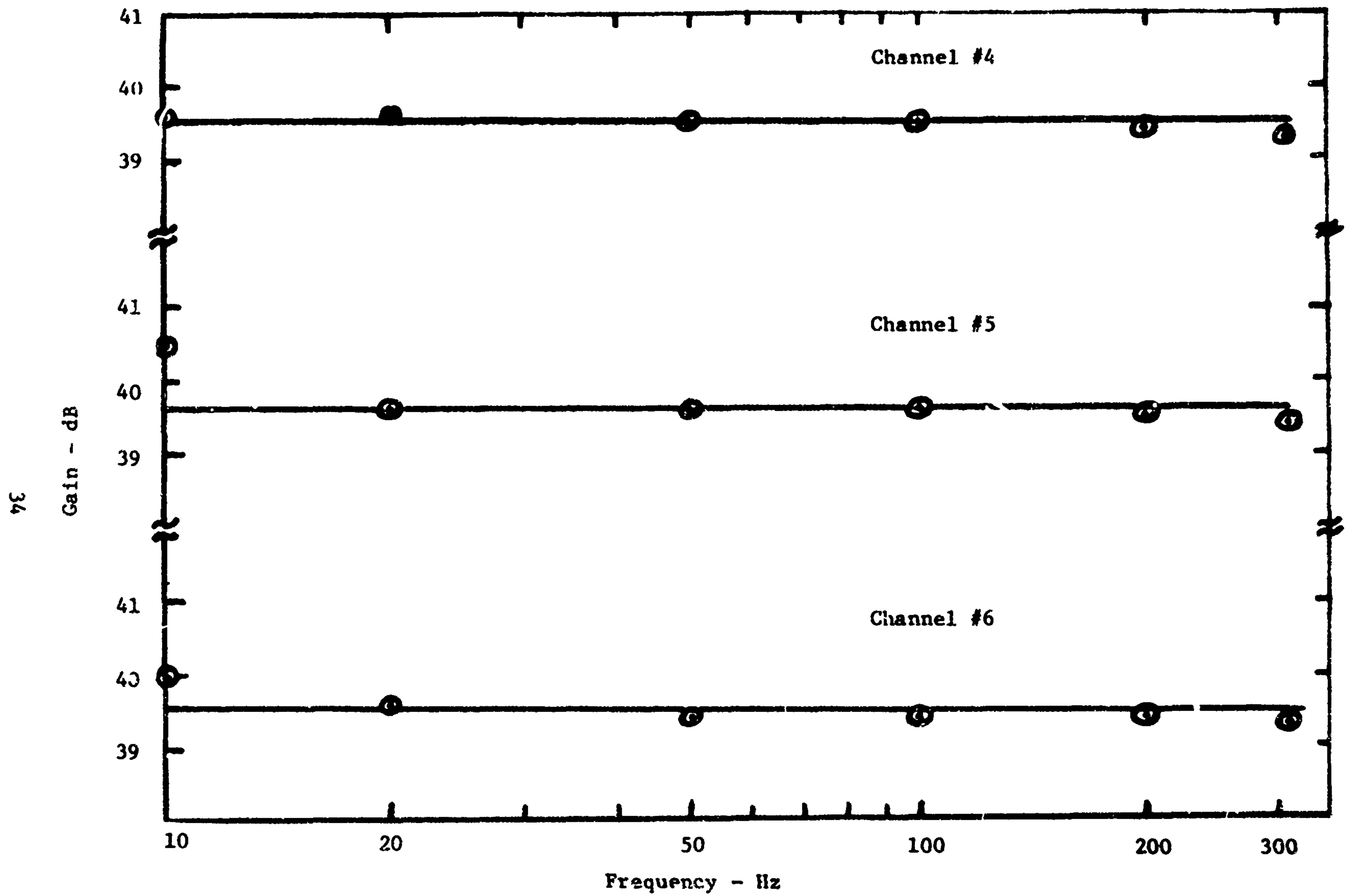

Fig.22 - Gains of Amplifier Channels

Measurements of input vs output voltage indicated that there was little saturation at output levels below 0.9 volt. At an output level of 0.9 volt the amount of second harmonic voltage was 36 dB below the fundamental. Figure 23 shows how the second harmonic distortion voltage varied as a function of output level.

The cross talk between any two channels was found to be less than -60 dB from 20 Hz to 300 Hz and less than -35 dB at 3 kHz. With an acoustic signal into five channels at 100 Hz, the signal coupled electrically into the sixth channel was at least 50 dB below the weakest acoustic signal to any of the other channels.

Self-noise measurements were made on all six channels using a wave analyzer that has a 6.3 Hz bandwidth. The results are shown in Figs. 24 thru 28. The dotted line gives the ocean ambient noise as given by the lower Wenz curve.

7.4 Galveston Tests

Tests were carried out on the North Seal in Galveston, Texas on May 25 and 26, 1973, and recorded as Tests #32 to #47. Since the cables between the top three hydrophones were not available, resistors were used to simulate the missing cables.

Cross talk measurements confirmed that there was little cross talk between channels. When an electrical signal was fed into channel #2, the level on channel #1 output was 50 dB below that of channel #2.

Linearity measurements indicated that all six channels produced an output voltage proportional to the input voltage up to a termination amplifier level of 0.90 volts. This is illustrated for channel #4 by Fig. 29.

Table 5 compares the measured input and output signals of all six channels when the termination output level was 900 mV.

Calibration signals at a level of 316 mV were recorded on the magnetic tape at frequencies of 12.5, 50, 100, and 250 Hz for channels #1 to #6. Each signal was applied for two minutes.

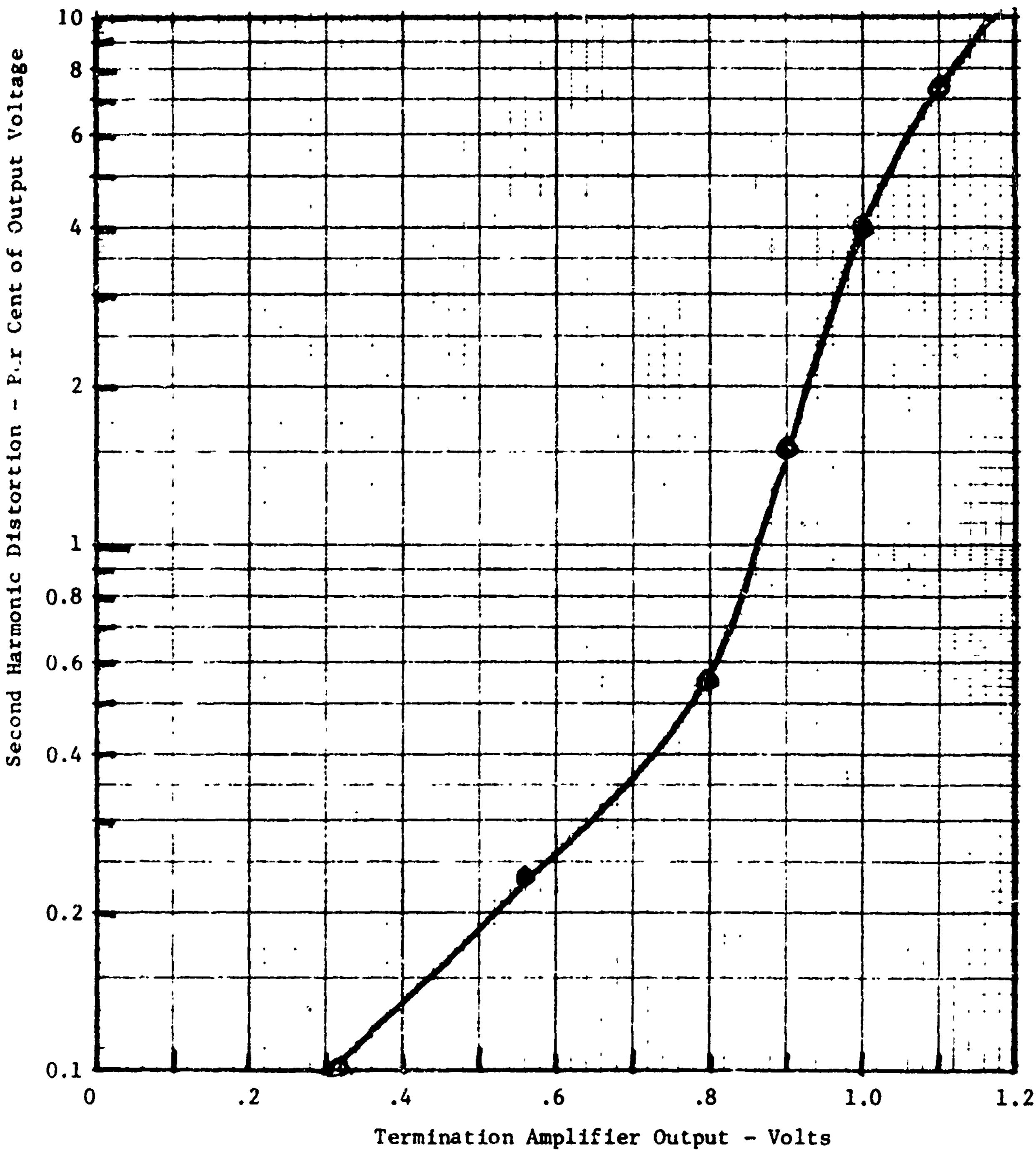

Fig. 23 - Harmonic Distortion

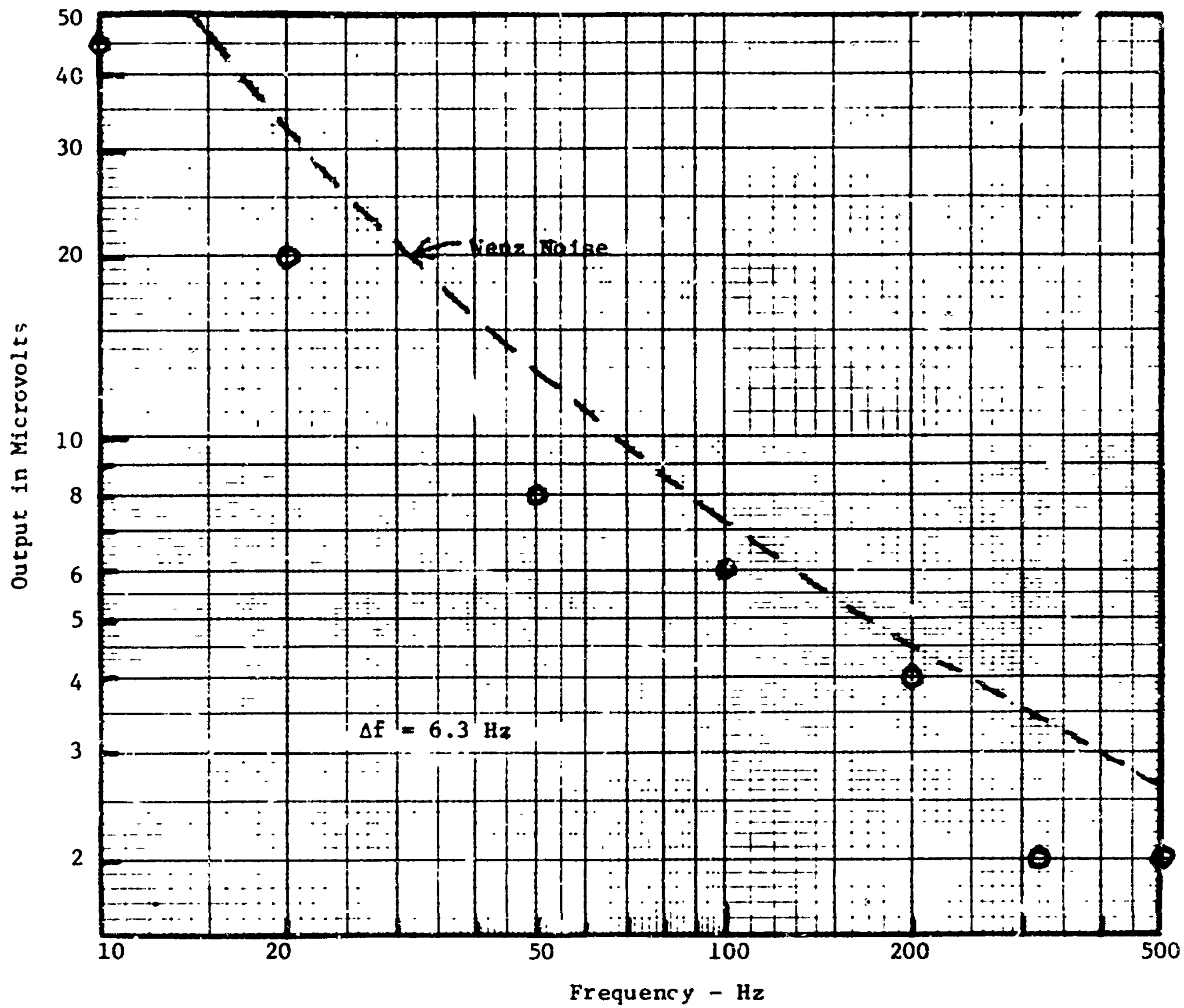

Fig. 24 - Self Noise of Channel #2

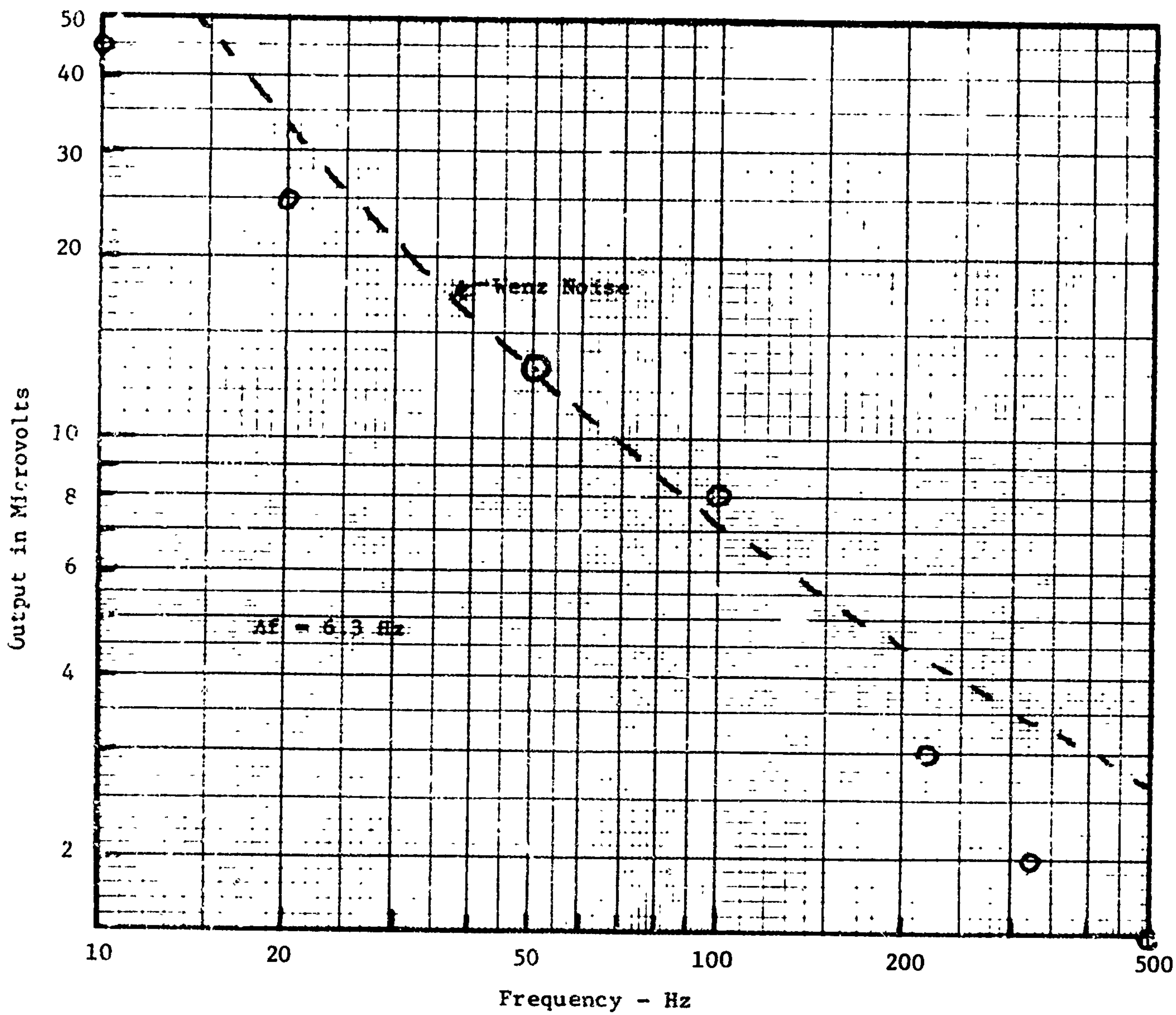

Fig. 25 - Self Noise of Channel #3

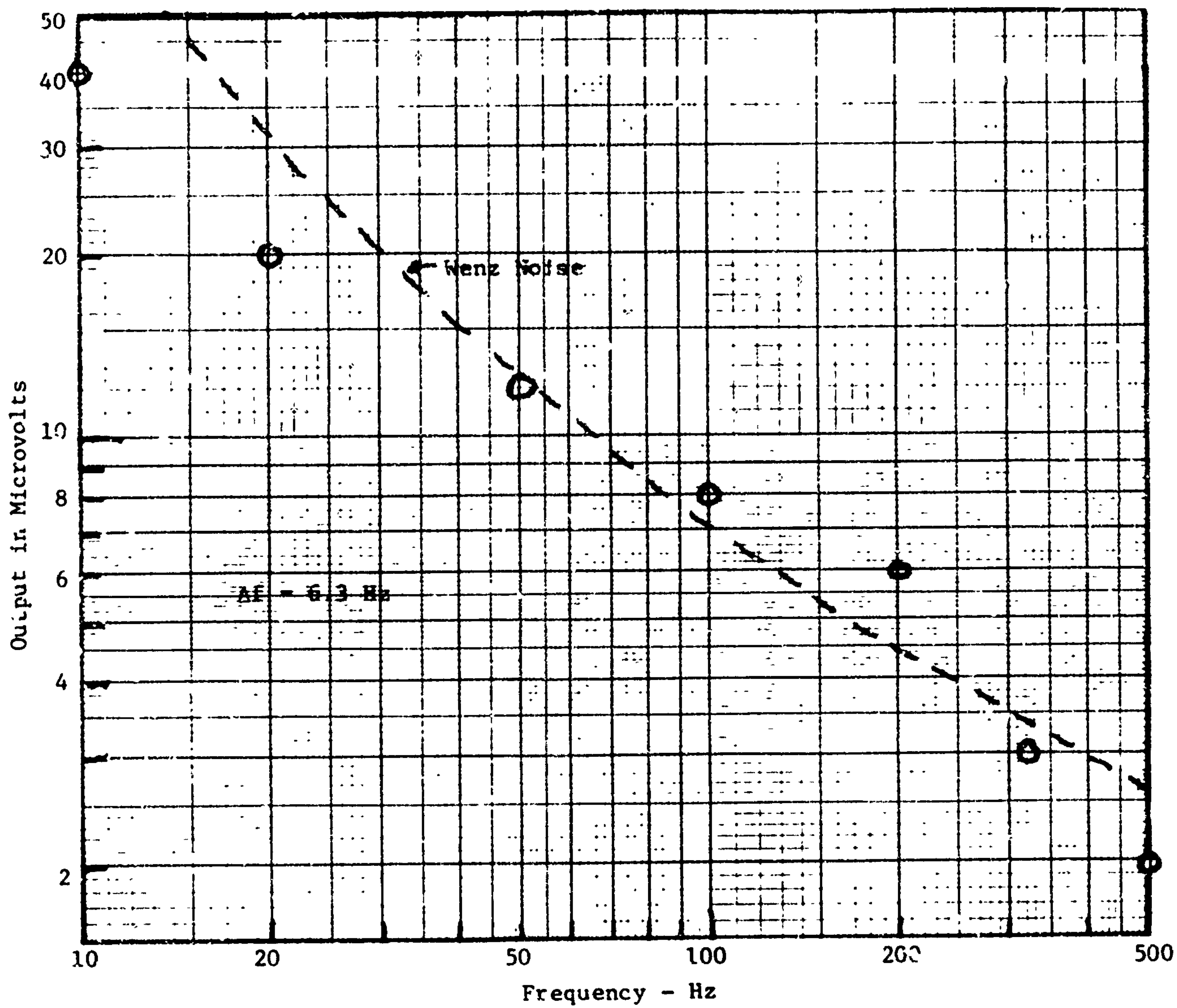

Fig. 26 - Self Noise of Channel #4

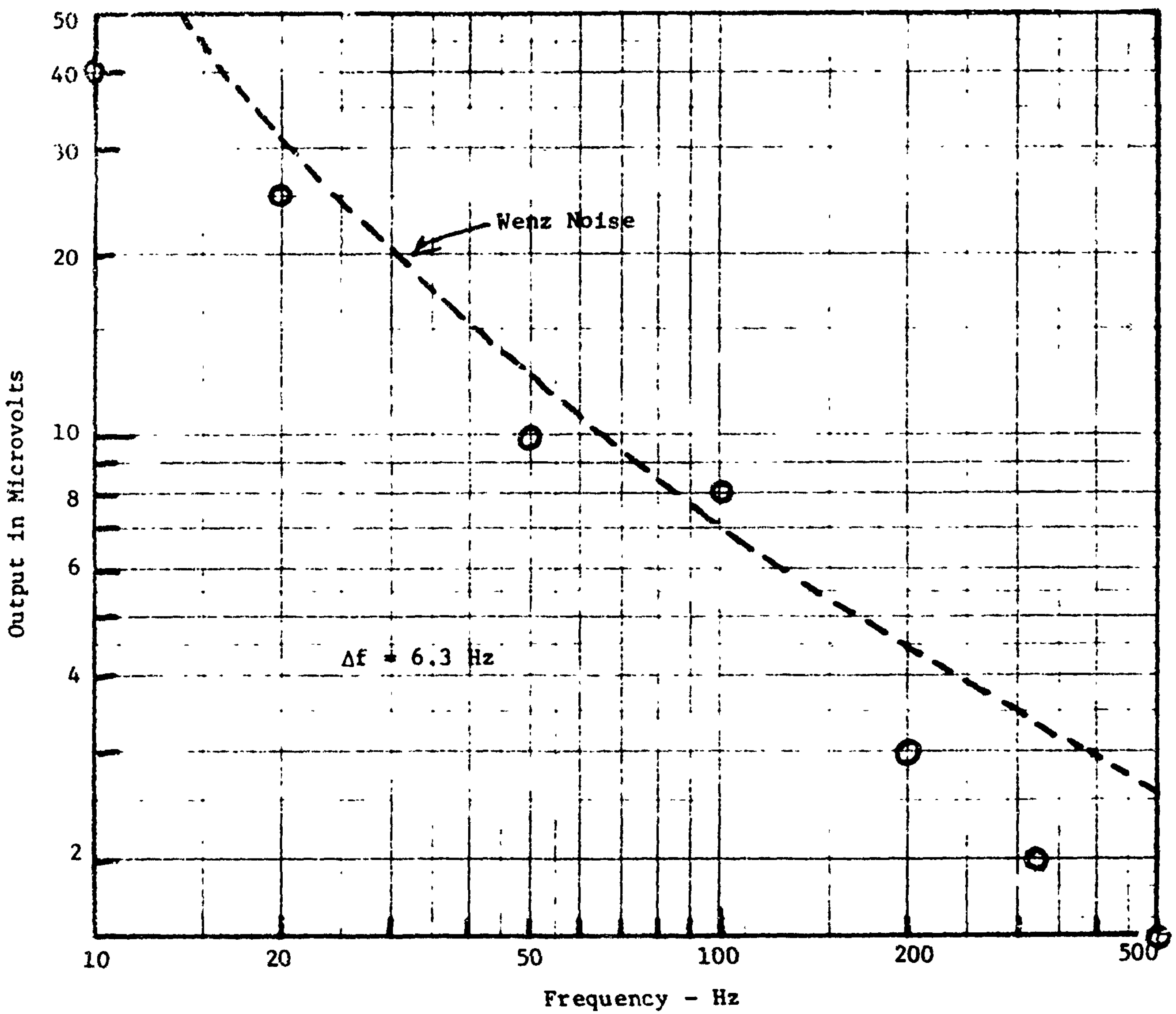

Fig. 27 - Self Noise of Channel #5

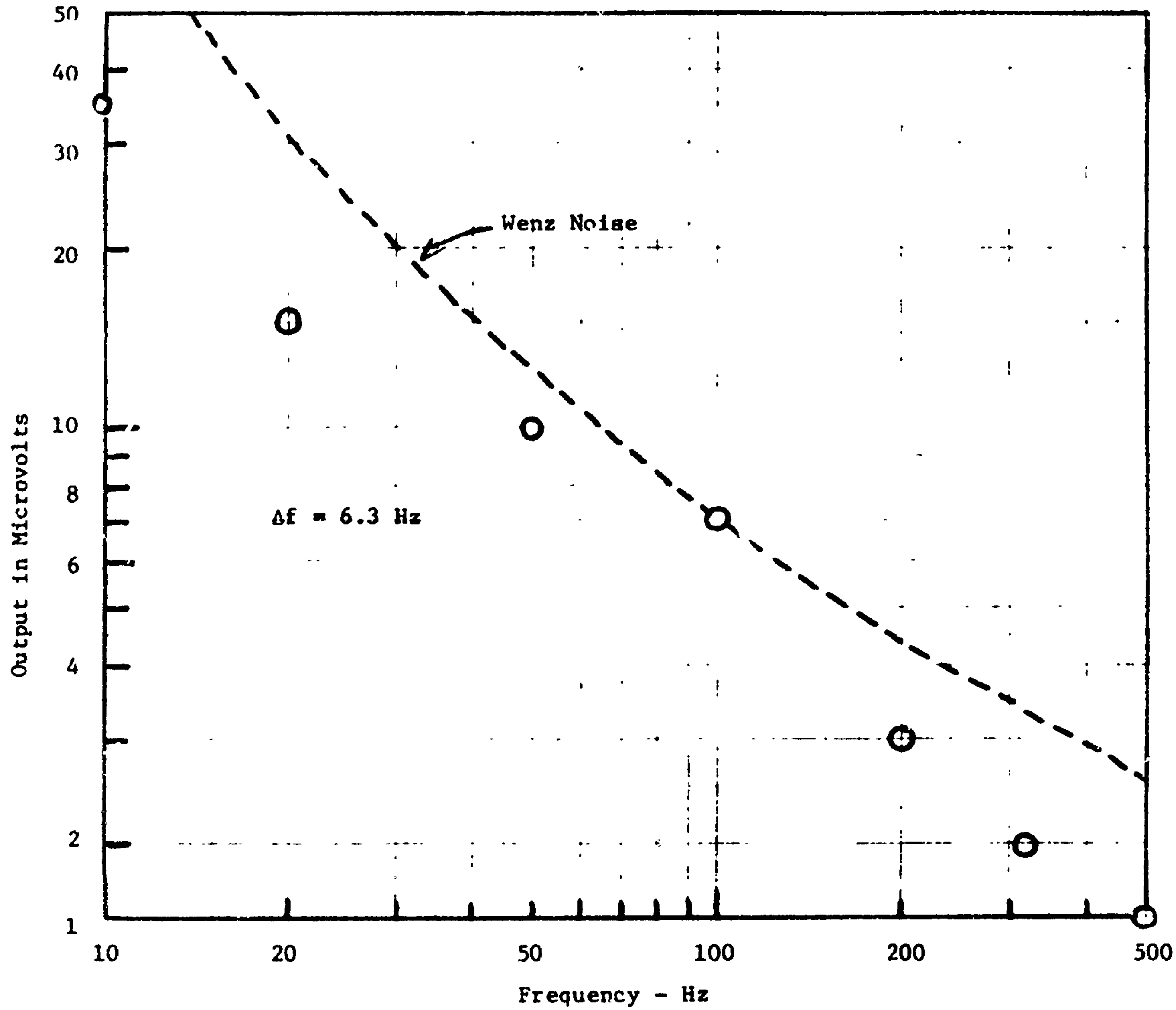

Fig. 28 - Self Noise of Channel #6

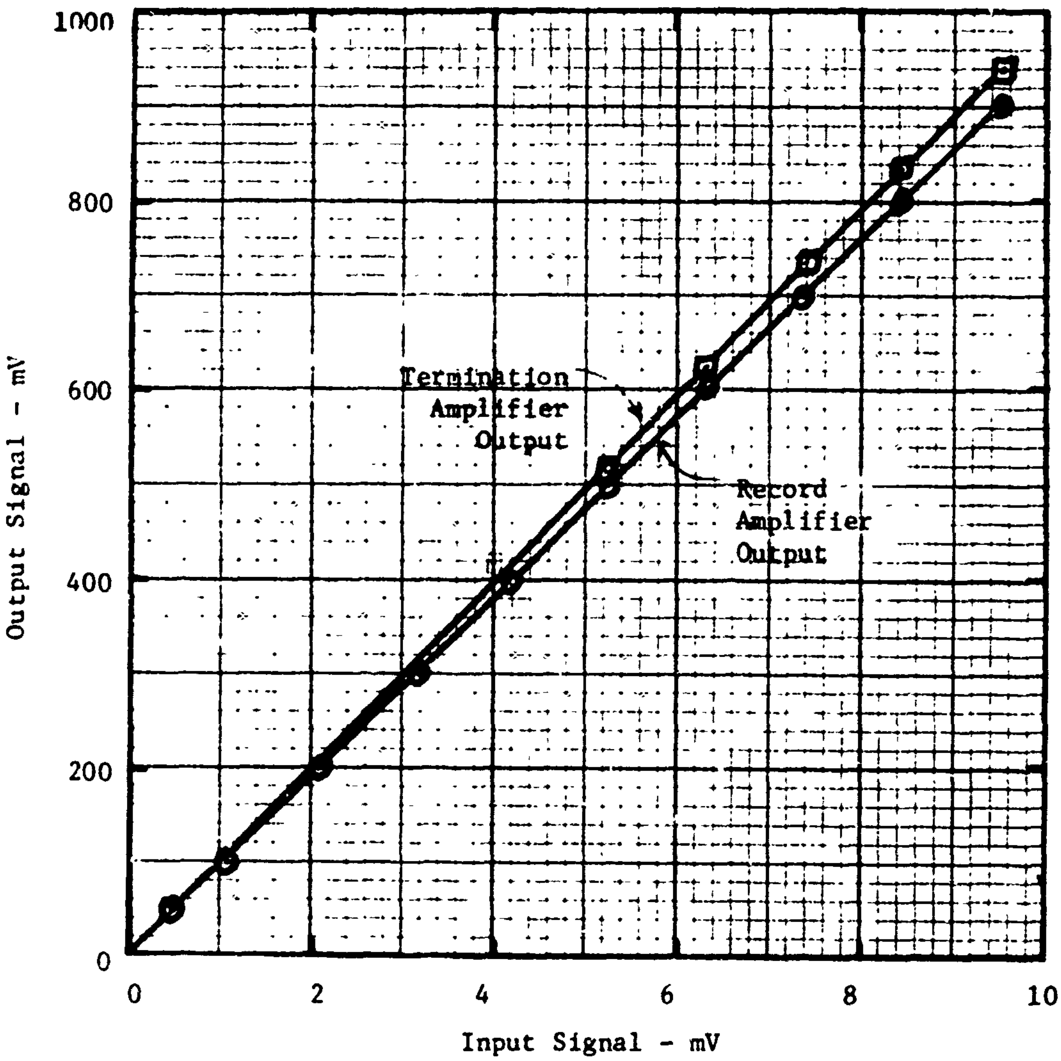

Fig. 29 - Channel #4 Linearity

TABLE 5

Comparative Gains of the Six Channels

Channel No.	Input Signal	Termination Amplifiers Output	Record Amplifiers Output
1	9.4 mV	900 mV	955 mV
2	9.4	900	950
3	9.5	900	940
4	9.5	900	940
5	9.4	900	935
6	9.5	900	945

The sensitivity of the termination amplifiers used in the deployment was 20 dB less than the termination amplifiers used for hydrophone calibration tests in Orlando. Table 6 gives the sensitivity of each hydrophone as measured in Orlando, the gain of the dummy preamplifier with the Orlando termination, the gain of the dummy preamplifier with termination Y, the difference in the two gains, and the resulting sensitivity of the hydrophones as used with the Y termination box. The true sensitivity of the hydrophones used with the Y termination is accurately found by adding the difference in gain to the sensitivity as measured by NRL.

TABLE 6

Sensitivity Calibration Measurements

Location	Hydrophone	Sensitivity measured by NRL at 100 Hz, 4°C and 55 MPa	Gain of preamp J with NRL Termination	Gain of preamp J with cables & Y Termination	Difference in Gain	Actual Sensitivity
		dB re 1 V/μPa	dB	dB	dB	dB re 1 V/μPa
1	A11	-135.4	59.8	39.4	-20.4	-155.8
2	A8	-130.7	59.8	39.4	-20.4	-151.1
3	A10	-131.9	59.8	39.5	-20.3	-152.2
4	A3	-130.5	59.8	39.5	-20.3	-150.8
5	A14	-131.3	59.8	39.6	-20.2	-151.5
6	A15	-130.9	59.8	39.4	-20.4	-151.3

8. CONCLUSIONS

Because of the intermittent behavior of some of the rejected amplifiers, new methods for encasing semiconductors have been evaluated since the Blake Tests. Future units will be pressure cycled 10 times to insure reliable performance in the ocean.

The split sleeve couplers will be made with a larger inside diameter so there is no danger of pinching the polyurethane surrounding the preamp unit.

Since the exact hydrophone sensitivity is a function of depth, the next time that hydrophones are calibrated, gain measurements will be made at four or five ambient pressures.

Cable strumming produces noise at about 3.5 Hz and so it is desirable for the hydrophone to have low sensitivity at that frequency. Consequently, an amplifier with a modified response will be built. The gain will be substantially flat from 10 Hz to 300 Hz but will be at least 10 dB less at 3.5 Hz.

The cross talk between channels was demonstrated to be very low.

9. REFERENCES

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
WHOI73-59	Tollios, C. D.	THE ACODAC DATA PROCESSING SYSTEM	Woods Hole Oceanographic Institution	730901	AD0773114; ND	U
Unavailable	Russell, J. J.	DOCUMENTATION FOR COMPUTER PROGRAM SUMMARY: A COMPUTER PROGRAM TO SUMMARIZE SOUND SPEED PROFILE DATA	Naval Undersea Center	731001	AD0918907	U
MC001Vol2	Unavailable	CHURCH ANCHOR DATA ANALYSIS PLAN VOL 2 (U)	Maury Center for Ocean Science	731001	ND	U
73-9M7-VERAY-R2	Jones, C. H.	LRAPP VERTICAL ARRAY- PHASE III	Westinghouse Research Laboratories	731105	ADA001130; ND	U
55	Weinstein, M. S., et al.	SUS QUALITY ASSESSMENT	Underwater Systems, Inc.	731201	~~ND~~ AD 785 875	U
ARL-TM-73-42	Mitchell, S. K., et al.	QUALITY CONTROL ANALYSIS OF SUS PROCESSING FROM ACODAC DATA	University of Texas, Applied Research Laboratories	731220	~~ND~~ ADB 000 263	U
Unavailable	Daubin, S. C.	CHURCH GABBRO TECHNICAL NOTE: CONTINUOUS CURRENT PROFILES	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740101	AD0775333	U
Unavailable	Bitterman, D. S.	ACODAC AMBIENT NOISE SYSTEM	Woods Hole Oceanographic Institution	740101	ADA009440	U
ONR MC-002 VOL. 2; XONICS 885	Unavailable	LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP). SQUARE DEAL DATA ANALYSIS PLAN (U) VOLUME 2 - ANNEXES	Maury Center for Ocean Science; Xonics, Inc.	740101	ND	U
ARL-TM-74-12	Groman, R. O., et al.	SPECIAL HARDWARE FOR ARL ANALYSIS OF ACODAC DATA	University of Texas, Applied Research Laboratories	740314	ADA000295; ND	U
Unavailable	Unavailable	ASEPS NEAR FIELD TRANSMISSION LOSS MODIFICATION, P-2205	Ocean Data Systems, Inc.	740401	ADA096583	U
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Unavailable	Gottwald, J. T.	ANNUAL REPORT FOR 1 MAY 1973 - 30 APRIL 1974	Tracor, Inc.	740524	AD0920210	U
Unavailable	Unavailable	ACOUSTIC MODEL SUPPORT ACTIVITIES, P-2220	Ocean Data Systems, Inc.	740530	ADA096584	U
HCI-CMC-18540	Daubin, S. C.	TRANSMISSION LOSS OF LOW FREQUENCY UNDERWATER SOUND IN THE CAYMAN TROUGH (CHURCH GABBRO TECHNICAL NOTE)	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740601	ADC000424; ND	U
HCI-CMC-18343	Daubin, S. C.	AMBIENT NOISE IN THE NORTHWEST CARIBBEAN SEA (CHURCH GABBRO TECHNICAL NOTE) (U)	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740601	ND	U
Unavailable	Barnes, A., et al.	DISCRETE SHIPPING MODEL	Planning Systems, Inc.	740604	ND	U